Memorandum To: Ron Minsk
National Economic Council

From: David Michaels, PhD, MPH
Assistant Secretary
for Environment, Safety and Health

Subject: Work Products from Inter-Agency Working Groups

Attached are work products from two Inter-Agency Working Groups formed by the National Economic Council in response to President Clinton's direction for a study of occupational disease among the Department of Energy (DOE) contractor workers.

As you know, on July 15, 1999, Secretary Richardson announced that the Administration would propose legislation to establish a new program to compensate victims of beryllium disease. At the same time, the President tasked the National Economic Council to coordinate an interagency process to examine whether other illnesses would warrant inclusion in such a program and how this should be accomplished. Experts in the fields of occupational medicine, public health, and social insurance were assembled to examine these issues. Staff from the Departments of Health and Human Services, Labor, Justice and Defense joined DOE in these efforts; the results do not therefore reflect the views of any particular agency.

The first paper examines the link between exposure to occupational hazards and illnesses in the DOE contractor workforce. The second reviews benefits available to DOE contractor personnel from state workers' compensation programs. The efforts of these two groups provide important input that will be useful in crafting a sound, science-based approach to the issues raised by the President: whether there are other occupational illnesses in DOE nuclear weapons complex, and, if so, how workers with these conditions should be compensated.

If you need additional information, please do not hesitate to contact me.

Executive Summary

The Link Between Exposure to Occupational Hazards and Illnesses In the Department of Energy Contractor Workforce

I. Background

This memo examines whether there is evidence of occupational illness in current and former contract workers at the US Department of Energy (DOE) from exposures to occupational hazards in nuclear weapons production and evaluates the strength of that evidence. To accomplish this task, an interagency panel of experts in the fields of public and occupational health reviewed the following sources of information related to the DOE workforce: 1) epidemiological studies completed and published either in the peer-reviewed literature as well as in technical reports; 2) information on the types and levels of exposures to workplace hazards; 3) special medical monitoring programs for workers with the highest exposures to ionizing radiation; 4) medical screening programs for former DOE contractor workers exposed to radiation as well as physical and chemical hazards; and 5) reports of illnesses presented to the DOE in public meetings or reported in the press.

The DOE and its predecessor agencies, principally the Manhattan Engineering District and the Atomic Energy Commission, consist of a nationwide network of 40 contractor-operated industrial sites and research laboratories that historically have employed over 600,000 workers in the production and testing of nuclear weapons. Because of this weapons production mission, health studies of DOE workers have focused primarily on the adverse health effects of exposure to ionizing radiation. Other non-radiation hazards have been studied at DOE sites only to a limited extent.

As a particular health outcome of concern associated with exposure to ionizing radiation is cancer, the panel also consulted the scientific literature in this regard. The 1994 United Nations Scientific Committee on the Effects of Atomic Radiation noted that cancers for which statistically significant excess risks have been determined from the Life Span Study mortality data are leukemia, breast, bladder, colon, liver, lung, esophagus, ovary, multiple myeloma and stomach. In addition, significant excess risk has been determined for the incidence of thyroid and skin cancers. The known and possible associations between radiation exposure and the above cancers tend to be based on populations exposed to relatively high levels of ionizing radiation (e.g., Japanese atomic bomb survivors, and recipients of selected diagnostic or therapeutic medical procedures). The question of cancer risk for chronic low dose levels or periodic higher levels of ionizing radiation exposure (e.g., such as may occur in certain occupational settings at DOE facilities) has not yet been completely studied. Other Health and Human Services literature suggests a possible association between ionizing radiation exposure and cancers of the prostate, nasal cavity/sinuses, pharynx/larynx, and pancreas. However, other National Cancer Institute literature indicates that other chemical and physical hazards and lifestyle factors (to include smoking, alcohol consumption, diet) contribute to many of these same diseases.

The panel examined all studies related to hazards and adverse health outcomes related to DOE's nuclear weapons production activities. The panel did not evaluate information on non-DOE populations, such as atomic bomb survivors or populations with occupational radiation exposures such as shipyard workers and medical personnel. Determining the causal links between an exposure and an illness was not considered to be within the mandate of this panel.

II. Findings

There is evidence from health studies of DOE workers that suggests that some current and former contractor workers at DOE nuclear weapons production facilities may be at increased risk of illness from occupational exposures to ionizing radiation and other chemical and physical hazards associated with the production of nuclear weapons. For certain facilities and for certain subgroups of workers within these facilities, some evidence suggests a strong association between employment and adverse health outcomes. Some studies indicate an increased risk of adverse health outcomes with increased levels of exposure to ionizing radiation.

Most DOE studies concerning the health status of its workers have been mortality studies. Evidence of health problems potentially related to exposures based on mortality studies is limited to specific facilities and causes of death. The identification of excesses of some types of cancers at some facilities and other types of cancers at other facilities is not surprising given the differences in past and present production processes, levels of exposure, and types of radiation and chemical hazards at these DOE facilities. Results from epidemiological studies must be interpreted with caution since a finding of a statistically significant elevation of disease does not alone imply causality. Conversely, the lack of a finding of excess disease in study does not imply that occupationally-related disease is absent in the study population. In addition, based on the studies reviewed, it is not possible to answer questions about the relationship between an individual's illness and that worker's occupational exposures.

Information evaluated by the panel from morbidity studies and medical surveillance programs for current and former DOE contract workers also provide evidence that these workers have suffered material impairment of health as a result of performing their jobs. However, before attempting to draw conclusions as to the health status of the overall population of former workers using this information, a number of factors must be considered. For example, the former worker medical surveillance program is in its initial phase with only preliminary results available. Further, participants in this program are selected from potential high-risk job categories and thus their health status may not be representative of the workforce as a whole. Nevertheless, the results from this program provide strong evidence that participating former workers at some facilities have experienced adverse health outcomes, particularly in the form of nonmalignant lung diseases. Mortality studies have also shown evidence that workers at several facilities have experienced excesses of nonmalignant lung diseases.

While the panel found credible evidence of occupational illness in current and former workers at DOE facilities, linking these illnesses to workplace exposures is limited by several factors: 1) there may have been inaccuracy and inconsistency in the radiation dosimetry monitoring program at certain facilities and during certain time periods; 2) there is a general lack of industrial hygiene monitoring data for chemical and physical hazards as well as other important non-occupational exposures such as smoking history; 3) not all workers at a given facility (such as female and minority workers) nor all facilities were included in the studies; 4) in some studies there may be a insufficient length of follow-up for some health outcomes (with long latencies) and for some worker cohorts (where they are not reaching the age where certain diseases such as cancers more commonly occur); 5) the potential that a healthy worker effect may obscure associations in some studies; 6) there was a tendency in these studies to focus on mortality, an extreme manifestation of injury or illness, yet most health conditions do not tend to be immediately fatal; and 7) often the size of a study population at a given facility decreases the ability to detect a health problem (a problem that cannot be overcome by grouping various cohorts together from different facilities due to the substantial variation in work tasks, processes and exposures from site to site).

The Link Between Exposure to Occupational Hazards and Illnesses In the Department of Energy Contractor Workforce

I. Background

On July 15, 1999, President Clinton issued a Memorandum to the Secretaries of Defense, Labor, and Energy, the Attorney General, the Director of the Office of Management and Budget, and the Assistant to the President for Economic Policy regarding occupational illness compensation for DOE contractor personnel. The Memorandum indicated the Administration's intent to submit legislation to create a program to give DOE contractor employees with chronic beryllium disease (CBD) and beryllium sensitivity compensation benefits similar to those available to Federal employees. Such legislation was submitted to Congress on November 17, 1999. In addition, the July 15th memorandum established an interagency review coordinated by the National Economic Council (NEC) to assess, by March 31, 2000, whether there are other illnesses that warrant inclusion in this program and how this should be accomplished.

In determining whether and how other illnesses should be included in this program, three tasks were designated. The first task is the subject of this memo.

From October 1999, through January, 2000, a panel of experts from a wide spectrum of federal agencies (Appendix 12) met to address the following questions:

1. What is the evidence that current and former contractor workers at DOE facilities are at increased risk of illness resulting from exposures to occupational hazards uniquely associated with nuclear weapons production?

2. How strong is this evidence?

To answer these questions, they examined and evaluated information and data from a variety of sources including current and historical exposure hazards at DOE facilities related to nuclear weapons production, as well as epidemiologic, other health studies and surveillance activities conducted among DOE contractor workers. In evaluating these data, the panel considered reviews of DOE's epidemiologic research program that have been conducted by different groups.[1, 2, 3] Although data from other radiation exposed cohorts, most notably nuclear shipyard workers, were discussed by the

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[1] Geiger HJ, Rush D, Michaels D. Dead Reckoning: A Critical Review of the Department of Energy's Epidemiologic Research. Physicians for Social Responsibility. Washington, DC. 1992.

[2] Report to the Secretary. The Secretarial Panel for the Evaluation of Epidemiologic Research Activities for the US Department of Energy. March 1990.

[3] US General Accounting Office. Problems in assessing the cancer risks of low-level ionizing radiation exposure (2 volumes). Washington DC: GPO, January 2, 1981.

panel members, the results of these studies are not included in this report due primarily to the limited focus and charge of this panel.

The findings expressed in this document represent the views of the technical experts who were members of the panel and not the individual agencies that provided the panel members.

II. Nuclear Weapons Production & DOE Operations

The Department of Energy and its predecessor agencies, principally the Manhattan Engineering District and the Atomic Energy Commission, have been engaged primarily in an extensive industrial enterprise to build and test nuclear weapons. For more than half a century, DOE has owned and its contractors have operated a nationwide network of heavy industrial sites as well as research laboratories involved in every aspect of weapons production from the refining of raw materials to the eventual testing of the bombs, and ultimately to the management of the weapons stockpile and the environmental consequences of nuclear production and testing.[4] It has been estimated that 5.5 trillion dollars (in 1996 dollars) have been spent since 1940 on U.S. nuclear weapons and weapons-related programs[5] and that upwards of 600,000 workers were involved in the construction, maintenance, operations, and scientific activities at DOE-owned facilities.

Figure 1 (Appendix 1) summarizes the process used to produce nuclear weapons. At each stage of the nuclear weapons cycle, from refining the raw materials to weapons assembly and finishing, to waste management and disposal, the principal materials used and primary exposures are listed. This figure is by no means a complete inventory of the potential health hazards that exist during the complex process of producing a nuclear weapon. For a more complete understanding of the potential chemical hazards involved in its operations, DOE has published a description of chemical vulnerabilities at its sites.[6] In addressing its charge, the NEC Task 1 panel examined evidence of illnesses from two classes of exposure: radiation and chemicals.

II. Radiation Exposures

Radiation protection and control programs have constituted a major focus of worker safety and occupational health efforts at DOE sites. Since the inception of the Manhattan Project, scientists have cautioned that exposure to ionizing radiation may

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[4] Linking Legacies. Connecting the Cold War Nuclear Weapons Production Processes to their Environmental Consequences. DOE/EM-0319 US Department of Energy. January 1997.

[5] Atomic Audit, the Costs and Consequences of U.S. Nuclear Weapons since 1940. S.I. Schwartz, editor. The Brookings Institution, Washington, D.C. 1998.

[6] Chemical Safety Vulnerability Working Group Report, 1994, U.S. Department of Energy, DOE/EH-0396P; DOE/EH-0398P

involve some risk. The National Committee on Radiation Protection and Measurements in 1954[7] and the International Commission on Radiological Protection in 1958[8] both recommended that exposures should be kept as low as practical and that unnecessary exposure should be avoided to minimize this risk. This has been a guiding principle of radiation exposure protection programs for the nuclear weapons workforce.

The majority of reported DOE radiation exposure data is based on dosimeters worn by contractors to measure external ionizing radiation. These dosimeters were primarily film badges until the early 1970s when solid state thermoluminescent detectors (TLDs) were adopted. The unit of measurement for external whole-body radiation exposure is the Deep Dose Equivalent (DDE) which is defined as the dose equivalent (the product of the absorbed dose and quality factor for the radiation) at a depth of 1 cm in tissue. The time period between badge readings was largely determined by the occupational standards of the time. In the 1950s the occupational limit was a weekly limit, in the 1960s a quarterly limit was established and since the 1970s the primary limit is an annual limit. Each DOE site has been expected to determine who needs to wear a dosimeter and how often to exchange dosimeters based on working conditions at that site. As a result, dosimetry badging practices varied from site to site and from contractor to contractor. In addition, there are reputable reports of isolated instances of incomplete and inaccurate personnel radiation dosimetry records.[9, 10]

Dose records go as far back as the establishment of the Manhattan Engineering District. These records are available at the sites and have been used in published health studies. Prior to 1974 annual doses of less than 10 mSv (1 rem) did not have to be reported to the Atomic Energy Commission (AEC). Starting in 1974 the AEC began collecting data on the number of individuals with measurable exposure (greater than the limit of detection for the monitoring system) which is a subset of all monitored individuals. Many personnel were monitored as a matter of prudence although a significant fraction did not receive a measurable exposure. The number of individuals with measurable exposure is a better indicator of the exposed workforce.

Personnel dosimetry was not necessarily provided to all DOE contract workers. The current version of Chapter 10 of the Code of Federal Regulations, Part 835 (§835.402(a)) prescribes issuing personnel dosimeters to radiological workers if they are

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7 National Committee on Radiation Protection and Measurements Report 17, "Permissible Dose from External Sources of Ionizing Radiation."

8 International Commission on Radiation Protection Publication 1, "Recommendations of the International Commission on Radiological Protection" (Adopted September 9, 1958), Pergamon Press, 1959.

9 Worker Safety at DOE Nuclear Sites," Hearing before the Subcommittee on Oversight and Investigation of the Committee on Energy and Commerce, U.S. House of Representatives, March 17, 1994.

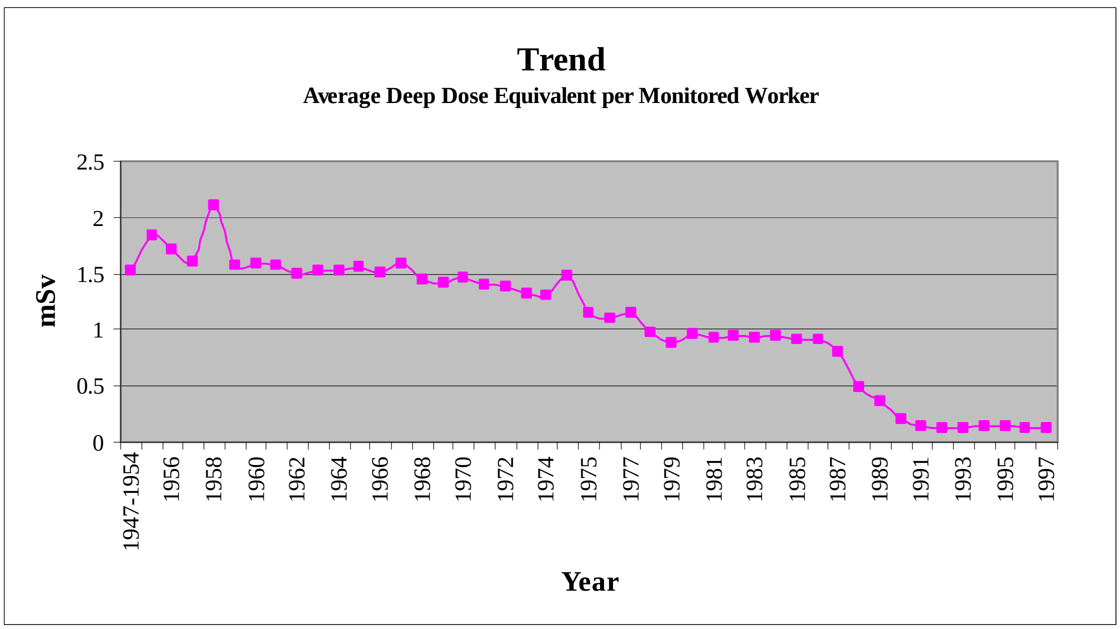
10 D.J. Strom et.al, "Doses to Workers in the United States Nuclear Weapons Program due to External Irradiation at the Dawn of the Atomic Era (1940-1960), Health Physics, 1996; 71:50-57.

likely to receive "an effective dose equivalent to the whole body of 100 mrem (0.001 Sv) or more in a year." Hence, individual dosimeters need not be issued to workers who are not expected to receive radiation exposures in excess of this limit. Consequently, there can be gaps in the data for radiological exposures to DOE contract workers.

The authors of a 1993 DOE technical report note that "it appears that there was a systematic underestimation of doses for Oak Ridge National Laboratory workers" and that "workers employed prior to 1957 are likely to have had doses that were higher than those recorded."[11] Therefore, it is possible that there may have been some inaccuracy and inconsistency in the radiation dosimetry program at certain DOE facilities during certain time periods.

The historic distribution of dose for the DOE workforce is shown in the figure below. The decline in average dose between 1986 and 1991 was due to the cessation of nuclear weapons production and the shutdown of numerous reactors used in their production.

Historic External Dose Distribution for the DOE Workforce



Tables 1 and 2 (Appendix 2) list the results of external radiation monitoring for the periods 1947-1974 and 1974-1997. As a point of reference, members of the general U.S. population receive an average annual effective dose equivalent of 3.6 mSv (0.36 rem)

11 Mitchell TJ, Istriycgiv G, Frime EL, Kerr GD. A method for estimating occupational radiation dose to individuals, using weekly dosimetry data. Oak Ridge National Laboratory Report ORNL-6778, December 1993.

from natural, enhanced natural and man-made sources of ionizing radiation. The table below summarizes the sources of these exposures.[12]

Annual Effective Dose Equivalent in the US population

Source	**Average Annual Dose (mSv)**
Natural Sources	
Cosmic	0.27
Cosmogenic (e.g., carbon-14)	0.01
Terrestial	0.28
In the body	0.39
Radon	2.00
Occupational	0.009
Nuclear Fuel Cycle Facilities	0.0005
Consumer Products	
Tobacco*	--
Other**	0.05 to 0.13
Miscellaneous Environmental Sources	0.0006
Medical	
Diagnostic x-rays	0.39
Nuclear medicine	0.14
Rounded Total	3.6

* effective dose equivalent for tobacco is difficult to determine; dose to a segment of the bronchial epithelium is estimated to be 0.16 Sv/y)16 rem/y)

** includes uranium and thorium-containing building materials and supplies, ophthalmic glass, and domestic water supplies.

III. Chemical Exposures

It has been estimated that more than 40,000 different chemicals are present throughout the DOE complex, and some, such as solvents and degreasers, are used in vast quantities. Most of these chemicals are not unique to DOE sites and are found in other industries. However, little is known about the actual levels of worker exposure to these materials. DOE does not maintain a centralized repository of industrial hygiene information on exposures to individual chemicals. To further complicate matters, exposures are often to mixtures of substances making a risk assessment based on the known toxicological profiles of these materials nearly impossible.

[12] National Committee on Radiation Protection and Measurements Report 93, "Ionizing Radiation Exposure of the Population of the United States," 1987.

While chemical hazards have not been either well documented or studied at DOE, a number of reports suggest, either directly or indirectly, that chemical hazards pose a significant health risk to both current and former DOE workers.[13, 14, 15] These risks may exceed those posed by radionuclides. An example of a non-radiogenic exposure is beryllium, a hazard that is specifically excluded from this report (since it is already covered under separate legislation proposed by the Administration and introduced in Congress as S.1954 and H.R. 3418). Exposure by DOE contractor workers and the resulting health conditions associated with beryllium exposure[16] served as a basis for the Presidential Memorandum of July 15, 1999, and as the origin of this examination.

IV. Findings

A. Summary of Major Findings From DOE Epidemiologic Studies

1. Background

Mortality studies of DOE workers began in 1964 and have continued through the present. The patterns of mortality have been the primary focus of these studies, particularly cancers from ionizing radiation exposure. More than 40 studies of DOE contractor workers have been completed to date; there are more than 20 additional studies underway. The studies cover fourteen of the nineteen principal DOE facilities excluding most of the private facilities that supplied DOE. When excess mortality was noted or a trend identified for a specific cause of death, special in-depth studies were often undertaken.

The studies concentrated primarily on production workers. At those sites where construction workers were employed as part of a prime contract, they would have been included in the site's study, but not analyzed as a separate group. Construction workers employed by the Zia Company at the Los Alamos National Laboratory were the one exception where a separate analysis of their mortality experience is reported. The studies include workers employed from 1944 to 1986 with results emphasizing those employed during the period of greatest production activity across the DOE weapons complex between 1944 and 1979. Due to changes in the DOE's mission with the

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13 Hazards Ahead: Managing Cleanup Worker Health and Safety at the Nuclear Weapons Complex. US Congress. Office of Technology Assessment. OTA-BP-O-85. Washington, D.C.: U.S. Government Printing Office, February 1993.

14 Comparative Carcinogenicity of Ionizing Radiation and Chemicals. National Council on Radiation Protection and Measurements. NCRP Report No 96. Bethesda, MD. March 1, 1989.

15 Radiation Protection in the Mineral Extraction Industry. National Council on Radiation Protection and Measurements. NCRP Report No 118. Bethesda, MD November 30, 1993.

16 Beryllium Biomarkers: Application of Immunologic, Inflammatory, and Genetic Tools. Lee S. Newman. Pages 285-300 in Biomarkers: Medical and Workplace Applications. Joseph Henry Press. 1998, Washington D.C.

cessation of the nuclear arms race and various international arms limitations agreements, results of these historical studies no longer reflect current workplace conditions.

Types of ionizing radiation exposures that have been studied include those exposures from external sources as well as exposures from internal depositions of plutonium and polonium, tritium and uranium dust. In addition, exposures to metallic mercury, nickel and nickel oxides, phosgene, and epoxy resins have also been studied. The nature and degree of exposures varied greatly from site to site depending on the operations and production at a given site. Historically, white males were the primary subjects of these studies. More recent studies and most new studies examine the impact on exposures to both non-white and female workers as well.

Human data from non-DOE cohorts on cancer induction by radiation are extensive. The most comprehensive studies involve the survivors of the atomic bombings of Hiroshima and Nagasaki, X-rayed tuberculosis patients, and persons exposed during treatment for ankylosing spondilitis, cervical cancer, and tinea capitis. Cancers either frequently or occasionally associated with radiation include leukemia, thyroid, female breast, lung, stomach, colon, esophagus, bladder, ovary and myeloma.

Lifestyle factors (e.g., smoking, diet, alcohol) and occupational exposures (e.g., benzene, dyes) may contribute to some of these radiation-induced cancers. Age at exposure, dose, dose rate and other factors may also influence the results of a particular population-based study as well as modify an individual's risk for disease.

2. <u>Findings</u>

- Statistically significantly elevated mortality rates were reported for some cancer types at some facilities, among specific subgroups of workers, and for specific time periods of employment (see table on next page).

- Overall, DOE production workers had significantly lower age-adjusted death rates compared to the U.S. general population for all causes of death combined; there were two exceptions (Appendix 5 references LIND87, ORK96).

- The relationship between mortality and exposure to ionizing radiation has been investigated for some but not all of the DOE cohorts. An increase in the risk of dying from specific conditions has been associated with increased exposure to external radiation exposure in seven cohort studies and to internal exposure in two studies. When these positive trends for mortality by level of ionizing radiation were observed, they were based on small numbers of deaths (less than five) among workers with the highest lifetime radiation doses. (Appendix 5 references HAN89, HAN93a, LANL94, MCW98, MND91b, ORX 91, ORC 97a, RAI97, SRS94.)

- Special studies of workers with brain cancer, multiple myeloma, malignant melanoma, non-malignant respiratory diseases, and malignant respiratory diseases were pursued. Except for non-malignant respiratory disease among Fernald workers, the special studies did not identify specific occupational exposures associated with the conditions.

A review of studies and findings by site is found in Appendix 3. Appendix 4 contains a listing of the Standardized Mortality Ratios (SMRs) for all causes of death for DOE workers (Table 1), summaries of statistically significant elevated SMRs for cancer and non-cancer causes of death by DOE site (Tables 2-1, 2-2 respectively), and a summary of statistically significant SMRs both increased and decreased for each cause of death among DOE workers (Table 3).

A list of the peer-reviewed and other publications relating to epidemiologic studies of DOE workers used to generate these summaries and tables is found in Appendix 5.

SUMMARY OF STATISTICALLY SIGNIFICANT ELEVATED FINDINGS FOR CANCER AT DEPARTMENT OF ENERGY (DOE) SITES

*Type of Cancer**	Fernald Plant	Hanford Site	Lawrence Livermore National Laboratory	Linde Air Products Ceramics Division	Los Alamos National Laboratory	Mallinckrodt Chemical Works	Mound Plant	Oak Ridge Combined (All facilities)	Oak Ridge National Laboratory (X-10)	Oak Ridge Y-12	Oak Ridge K-25	Rocketdyne/Atomics International	Rocky Flats Plant	Savannah River Site
Salivary gland			I											
Esophagus					T									
Stomach	S													
Rectum			I				S							
Liver		T												
Pancreas		S,T												
Larynx				S										
Trachea, bronchus & lung					S		S	S		S	S	T		
Bone											S			
Skin – malignant melanoma			I											
Genital cancer		T												
Prostate							S	S						
Bladder											I			
Kidney					T	T								
Brain & other CNS					T									
Lympho- & hemato-poietic												T	T	
Leukemia - all types							T		S					S,T
Leukemia – lymphocytic					T									
Leukemia – chronic lymphocytic														S
Hodgkin's lymphoma		T			T									
Multiple myeloma		T												
Upper aero-digestive tract												T		

Legend:	S **– SMR study with statistically significant finding for specific organ site cancer** T **– Statistically significant trend analysis for radiation versus indicated cancer** I **– Incidence study with statistically significant finding for specific organ site cancer**

Note: A full description of the associations and definitions contained in the table can be found in the text under "Major Findings," Appendix 3.
*** - Listed in order of appearance in the International Classification of Diseases (ICD) 8th revision**

B. Summary Of Findings Related To Chemical Hazards At DOE Sites

1. Background

Appendix 6 lists those chemical hazards most commonly cited in either environmental studies around DOE sites and/or in health studies of DOE workers. These chemical are only a small fraction of the estimated 40,000 chemicals that have been used at DOE facilities. Appendix 1 outlines the major steps in the production of nuclear weapons and the radiation and non-radiation hazards associated with each step of the process. Appendix 7 summarizes the principal weapons production processes by site. Only a few of the chemicals used at DOE facilities have been examined in epidemiologic health studies of its workers.

2. Findings

- Mercury Workers: Studies of exposure to metallic mercury were significantly associated with clinical neurologic abnormalities in the most highly exposed group (ORY88a, ORY97).

- Centrifuge Workers: An increased incidence of bladder cancer was observed among gas centrifuge manufacturing workers. Although epoxy resins and solvents were commonly used in the gas centrifuge manufacturing process, the observed higher incidence of bladder cancer among gas centrifuge workers was not associated with exposure to these substances.

- Welders: The most recent study of welders revealed higher risk of death from lung cancer, prostate cancer, and stomach ulcers. The risk for lung cancer was not related to nickel exposure. The potential contribution of thorium exposure to the observed increased risk was not evaluated in the welders studies.

C. Summary of Findings From Special Radiation Workers Monitoring Programs

1. Background

DOE supports three specialized monitoring programs or studies of a relatively small number of workers with the highest exposures to ionizing radiation from radionuclides and/or external sources. These special programs include a tissue registry for post-mortem analyses of workers with known occupational exposure levels to radionuclides, periodic medical follow-up for plutonium-exposed workers (average dose 1,250 mSv [125 rem]), and a program of cancer screening for workers with the highest doses of external radiation (dose greater than 200 mSv [20 rem]). These specialized programs are described in Appendix 8.

2. Findings

- Specialized radiation worker studies have generally not shown unusual numbers or types of illnesses commonly associated with radiation exposure, even among workers with known high body burdens of radionuclides.

- One case each of osteosarcoma and lung fibrosis have been diagnosed among workers exposed to plutonium. Osteosarcoma is a rare cancer and is of interest because plutonium is known to deposit in the bone.

- Among the 244 causes of death in the tissue registries, cancer deaths from causes potentially or known to be associated with radiation exposure were identified (Appendix 8, Table 1).

- In addition, six confirmed cases of mesothelioma among DOE workers exposed to asbestos have been documented among the USTUR registrants.

D. Summary of Findings From Other Surveillance Programs

1. Background

DOE supports two injury and illness surveillance programs. The Epidemiologic Surveillance Program collects illness information from occupational medicine programs. The Computerized Accident/Incident Reporting System (CAIRS) is a centralized database that collects all contractor reports of injuries, illnesses, and other accidents. It is based on Department of Labor requirements for reporting these events. Data from DOE investigations of these reports are used to generate performance indicators used by the DOE to manage its safety and health programs, and to provide estimates of dollar loses due to work-related injuries, illnesses, and accidental property damage. Recent summaries of epidemiologic surveillance and CAIRS data are presented in Appendix 9.

2. Findings

- The Epidemiologic Surveillance Program reported cases of occupational illnesses among DOE workers that are consistent with the definition of a "Sentinel Health Event of Occupational origin [SHE(O)]" described in the medical literature.[17] In 1997, data summarizing these SHE(O)s from 8 DOE sites included 13 cancer and 7 respiratory disease diagnoses (Appendix 9, Table 1).

- CAIRS data from 1998 reported 659 cases of non-injury occupational health events among contractor workers at all DOE sites (Appendix 9, Table 2).

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[17] Rutstein DD, Mullan RJ, et al. Sentinel health events (occupational): A basis for physician recognition and public health surveillance. *Arch. Envir. Health* 39: 159-168; 1984.

- Both of these DOE-maintained surveillance systems allow for the identification of current illnesses and injuries in its workforce.

E. Initial Results From The Former Workers Program

1. Background

In response to a Congressional mandate, DOE recently initiated a medical surveillance program tailored specifically to examine former DOE workers felt to be at high risk for occupationally-related illnesses. Results from chest radiographic screening are presented below. There were other results of the initial screening examinations presented to the panel related to heavy metals, hearing loss, beryllium exposure and exposures to solvents and mixed chemicals. The panel concluded that the results of these examinations were too preliminary to include in the report. Preliminary results from the chest X-ray screening are presented in Appendix 10.

2. Findings

- Initially medical screening has found a relatively high proportion of abnormalities on chest X-ray among selected groups of former workers. Of the 882 individuals screened as of December 1999, 148 (17%) have International Labor Organization (ILO) category 1/0 or greater perfusion on their chest X-ray indicating the presence of a pneumoconiosis.

F. Input From The Public

1. Background

Beginning in August 1999, the Department of Energy initiated a number of outreach efforts to learn more about work-related health concerns from its current and former contractor workforce. These efforts included: 1) a series of public meetings in the communities surrounding its facilities to seek input from workers regarding their work-related health concerns and their experiences with filing for workers' compensation for these health problems; 2) establishing a toll-free "hotline" for workers to call in to ask questions and to relay any health concerns; and 3) distributing a questionnaire asking DOE employees about health concerns and their experience with workers' compensation systems (Appendix 11).

A summary of the nature of the health problems reported to the hotline and in the questionnaires is provided in Appendix 11, and a bibliography of media reports of illnesses among DOE workers both from these public meetings and independent of these sessions is also included in Appendix 11.

2. Findings

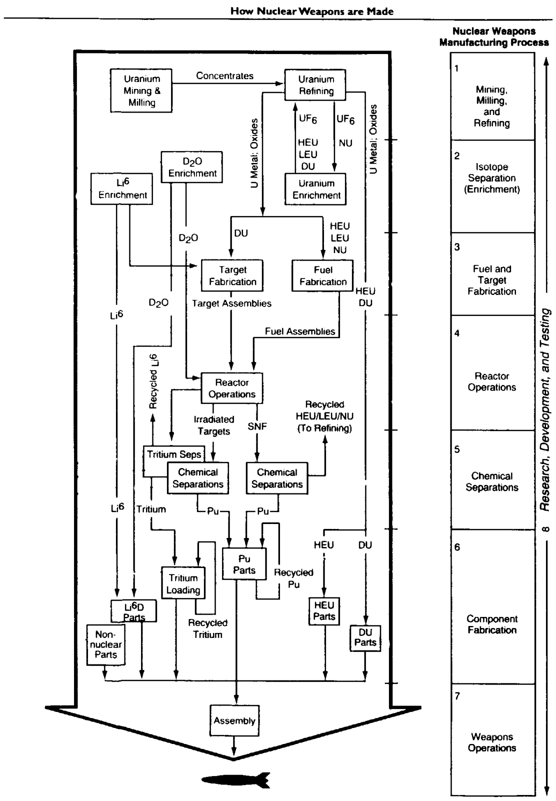
- The panel recognizes the importance of these reports in formulating policy regarding compensation for these illnesses. They clearly reflect the strong feelings among many workers that they have been made ill by workplace exposures at DOE. The panel did not independently review nor verify these reports. They may represent work-related illnesses that may not be reflected in the study data reviewed by the panel.

APPENDIX 1

PRODUCTION PATHWAY FOR NUCLEAR WEAPONS

Radiation and non-radiation hazards by process step

Production Pathway for Nuclear Weapons



Functional Process	Radiation Hazards	Non radiation hazards
Uranium is refined from ore and gaseous feed then shaped into metal	Internal deposition of uranium and its decay products through inhalation; external whole body exposure to ionizing radiation.	EMF, soluble uranium compounds; ammonia, nitrogen oxides, hydrofluoric acid, fluorides, and welding fumes.
Natural uranium is enriched in the uranium-235 isotope Natural lithium is enriched in the lithium-6 isotope Natural water is enriched in the hydrogen-2 isotope	Internal exposure to gaseous uranium compounds during sampling, cylinder loading and unloading, and maintenance operations; Internal deposition of uranium and its decay products; external exposure to ionizing radiation from cylinder handling, tritium and transuranics.	EMF, fluorides, fumes from welding and welding stainless steel piping, exposure to nickel when manufacturing diffusion barriers, sulfuric and nitric acids, and uranium chloride; hydrogen sulfide.
Uranium gas and metal is converted into metal fuel and target elements for production reactors. Targets include uranium-238 & lithium-6. Scrap metal is recycled.	Inhalation of uranium-235, 238 and its decay products, and tritium.	EMF, soluble uranium, and lithium hydroxide.
Uranium-238 slugs are irradiated to create plutonium metal Lithium targets are irradiated to produce tritium	Inhalation of fission products, activation products, external whole body ionizing radiation.	EMF
Irradiated fuels and targets are dissolved; plutonium, uranium and other fission products are extracted Chemicals are recycled	External whole body ionizing radiation, Inhalation of fission products and transuranic elements.	EMF, soluble uranium, nitric acid, kerosene and n-dodecane, tributylphosphate, hydrogen fluoride, calcium metal, sodium hydroxide.
Nuclear - Manufacturing, assembly, inspection, bench testing, and verification of nuclear components and major subassemblies. Chemical processing to recover, purify, and recycle plutonium, uranium, tritium, and lithium from retired warheads and production residual.	External whole body ionizing radiation, inhalation of radioactive materials (primarily transuranics), U-233.	EMF, soluble uranium, beryllium, nitric acid, kerosene, n-dodecane, tributylphosphate, hydrogen fluoride, calcium metal, sodium hydroxide.
Nonnuclear – Manufacturing, assembly, inspection, and benchtesting high explosives, fuses, detonators, timers, batteries etc.	External whole body ionizing radiation, inhalation of radioactive materials.	EMF, high explosives, solvents, beryllium, stainless steel, heavy metals, and materials used in electronics fabrication.
Assembly, maintenance and dismantlement of nuclear weapons	External whole body ionizing radiation.	All of the above.

Sources:

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APPENDIX 2

IONIZING RADIATION DOSES TO DOE EMPLOYEES

1947-1997

Table 1
Deep Dose Equivalent - Number of Individuals Receiving Radiation Doses in Each Dose Range
1947-1974

		[Dose	(Rem)]					
Year	0-1	1-5	5-10	10-15	>15	Total Monitored	Coll. DDE (person-rem)	Avg. DDE per Monitored
1947-1954	130,128	5,311	284	32	6	135,761	20,717	0.153
1955	56,708	3,157	285	41	1	60,192	11,026	0.183
1956	38,225	2,312	100	4	3	40,644	6,961	0.171
1957	45,510	2,424	83	5	1	48,023	7,706	0.160
1958	59,455	6,271	159	10	12	65,907	13,937	0.211
1959	71,600	3,912	66	2	1	75,581	11,835	0.157
1960	77,552	4,629	41	2	1	82,225	13,092	0.159
1961	90,651	5,174	40	3	8	95,876	15,112	0.158
1962	122,437	5,707	113		8	128,265	19,219	0.150
1963	107,786	5,472	80		1	113,339	17,221	0.152
1964	122,711	6,157	86	11		128,965	19,594	0.152
1965	128,360	6,671	175	8		135,214	21,147	0.156
1966	131,522	6,242	167		2	137,933	20,900	0.152
1967	102,510	5,767	108	1		108,386	17,156	0.158
1968	103,206	4,776	4			107,986	15,595	0.144
1969	98,625	4,288	4	1		102,918	14,610	0.142
1970	92,185	4,464	12			96,661	14,190	0.147
1971	90,640	3,661	12	1	1	94,315	13,178	0.140
1972	86,077	3,373	10			89,460	12,369	0.138
1973	89,071	2,903	3			91,977	12,116	0.132
1974	73,845	2,318	3			76,166	9,950	0.131

Note: Prior to 1974 annual doses of less than 1 rem were not required to be reported. Collective dose was not calculated or reported as well. Thus, to estimate collective doses for 1947-1974, a dose was assigned to each dose range as follows: 0-1=0.1; 1-5=1.1; 5-10=5.1; 10-15=10.1; and >15=15.1.

Table 2
Deep Dose Equivalent - Number of Individuals Receiving Radiation Doses in Each Dose Range
1974-1997

Year	Less Than Meas.	Meas. - 1	[Dose 1-2	(rem)] 2-3	3-4	4-5	>5	Total Monitored	No. with Meas. DDE	Coll. DDE (person-rem)	Avg. Meas. DDE	Avg. DDE per monitored
1974	29,735	1,531	652	149	40	4		69,171	32,111	10,202	0.318	0.147
1975	41,390	36,795	1,437	541	122	28	1	80,314	38,924	9,202	0.236	0.115
1976	38,408	41,321	1,296	387	70	6	1	81,489	43,081	8,938	0.207	0.110
1977	41,572	44,730	1,499	540	103	23	5	88,472	46,900	10,199	0.217	0.115
1978	43,317	51,444	1,311	439	53	11		96,575	53,258	9,390	0.176	0.097
1979	48,529	48,553	1,281	416	33	10	3	98,825	50,296	8,691	0.173	0.088
1980	43,663	35,385	1,113	387	16			80,564	36,901	7,760	0.21	0.096
1981	43,775	33,251	967	263	29	5		78,290	34,515	7,223	0.209	0.092
1982	47,420	30,988	990	313	56	28		79,795	32,375	7,538	0.233	0.094
1983	48,340	32,842	1,225	294	49	31		82,781	34,441	7,720	0.224	0.093
1984	46,056	38,821	1,223	312	31	11		86,454	40,398	8,113	0.201	0.094
1985	54,582	34,317	1,362	356	51	8	1	90,677	36,095	8,340	0.231	0.092
1986	53,586	33,671	1,279	349	35	1	2	88,923	35,337	8,095	0.229	0.091
1987	45,241	28,995	1,210	283	36			75,765	30,524	6,056	0.198	0.080
1988	48,704	27,492	502	34				76,732	28,028	3,735	0.133	0.049
1989	56,363	28,925	428	21				85,737	29,374	3,151	0.107	0.037
1990	76,798	31,110	140	17				108,065	31,267	2,230	0.071	0.021
1991	92,526	27,149	95					119,770	27,244	1,762	0.065	0.015
1992	98,900	24,769	42					123,711	24,811	1,504	0.061	0.012
1993	103,905	23,050	86			1		127,042	23,137	1,534	0.066	0.012
1994	92,245	24,189	77					116,511	24,266	1,600	0.066	0.014
1995	104,793	22,330	153					127,276	22,483	1,809	0.08	0.014
1996	101,529	21,720	74	1				123,324	21,795	1,598	0.073	0.013
1997	89,805	17,331	45					107,181	17,376	1,285	0.074	0.012

Note: Dose ranges lower for this table compared to Table 1.

APPENDIX 3

SUMMARY OF EPIDEMIOLOGIC STUDIES

Background

Epidemiology is the study of the distribution and determinants of illness and injury in human populations. This distribution is considered in relation to time, place, and person. Relevant population characteristics include the age, race, and sex distribution of a population, as well as other characteristics related to health, such as social characteristics (e.g., income and education), occupation, susceptibility to disease, and exposure to specific agents. Determinants of disease include the causes of disease, as well as factors that influence the risk of disease. There are three major study designs that are used in studies of workers and communities.

Study Designs

Cohort Studies. The cohort study design is a type of epidemiologic study frequently used to examine occupational exposures within a defined workforce. A cohort study requires a defined population that can be classified as being exposed or not exposed to an agent of interest, such as radiation or chemicals that influence the probability of occurrence of a given disease. Characterization of the exposure may be qualitative (e.g., high, low, or no exposure) or very quantitative (e.g., radiation measured in Sieverts (Sv), chemicals in parts per million [ppm]). Surrogates for exposure, such as job titles, are frequently used in the absence of quantitative exposure data.

Individuals enumerated in the study population are tracked for a period of time, their vital status (dead or alive) is determined at the time of the study, and cause of death is sought for the deceased member of the study population. In general, overall rates of death and cause-specific rates of death have been assessed for workers at DOE sites. Death rates for the exposed worker population are compared with death rates of workers who did not have the exposure (internal comparison), or compared with expected death rates based on the U.S. population or state death rates (external comparison) using a *standardized mortality ratio* (SMR).

The SMR is the ratio of the number of deaths observed in the study population to the number of expected deaths. An SMR of 100 indicates the same risk of disease in the study population compared with the reference population. An SMR greater than 100 indicates a higher risk of disease in the study population compared with the reference group, and an SMR less than 100 indicates a deficit of disease. If the rates of death differ from what is expected, an explanation is sought to account for the differences such as exposure to a carcinogen at work. In cohorts where the exposure has not been characterized, excess mortality can be identified, but these deaths cannot be attributed to a specific exposure, and additional studies may be warranted.

More recent studies have looked at disease endpoints other than death, such as overall and cause-specific cancer incidence (newly diagnosed) rates.

In situations where the total worker population at risk has not been identified, mortality rates cannot be calculated and risk cannot be estimated. When only deaths or illnesses are known an alternative approach is the *proportionate morality study*. This approach examines the proportional distribution of deaths from specific conditions in the study group relative to the same condition in the U.S. general or regional population. The resulting index is the Proportional Mortality Ratio (PMR). This approach is not powerful although it is useful in rapidly screening worker populations to identify conditions that may reflect occupational exposures.
Most cohort studies at DOE sites have been historical cohort studies, that is, the exposure occurred some time in the distant past. These studies rely on past records to document exposure. This type of study can be problematic if exposure records are incomplete or were destroyed. Cohort studies require populations that have been followed for many (20 to 30) years. They are generally difficult to conduct and are very expensive. These studies are not well suited to studying diseases that are rare. Cohort studies do, however, provide a direct estimate of the risk of death from a specific disease, and allow an investigator to look at many disease end points.

Case-Control Studies. The case-control study design starts with the identification of persons with the disease of interest (case) and a suitable comparison (control) population of persons without the disease. Controls must be persons who are at risk for the disease and are representative of the population that generated the cases. The selection of an appropriate control group is often quite problematic. Cases and controls are then compared with respect to the proportion of individuals exposed to the agent of interest. Case-control studies require fewer persons than cohort studies, and therefore, are usually less costly and less time consuming, but are limited to the study of one disease (or cause of death). These types of studies are well suited for the study of rare diseases and are generally used to examine the relationship between a specific disease and exposure.

Cross-Sectional Studies. In cohort studies, detailed knowledge of the time sequence of exposures relative to health outcomes is critical in “confirming” associations. Cohort studies are complicated, expensive and require considerable time to complete. A useful alternative to a cohort study that can provide evidence “suggesting” associations is a cross-sectional study. This type of study does not consider the time sequence of events leading up to an illness or injury. A typical cross-sectional study is the health survey where at a single point in time information about workers current health status and working conditions is collected. This approach is useful in rapidly screening worker populations to identify conditions that may reflect occupational exposures.

MAJOR FINDINGS

Because of the large number of studies and the many comparisons involved, only statistically significant higher rates and positive dose-response trends are reported. They are shown below in *italics*. Statistical significance reflects estimates that are based on a sufficient number of deaths to be judged reliable. Statistical significance by itself is not proof that the condition is due partly or in entirely to workplace exposures. Special studies were identified with a **bold** type face.

Fernald "Feed Materials Production Center" *(Reference prefix - FMPC)*

From 1951 to 1989 Fernald processed uranium and thorium into fabricated metal products for use in the defense programs. There were 4,014 white male employees included in the single cohort mortality study.

A. Cancer Causes of Death -- For deaths through 1989, the death rate for *stomach cancer* among salaried white males was higher than the rate for the U.S. population. Hourly males had higher rates for *all cancer combined* and *lung cancer*.

B. Non Cancer Causes of Death --For all males there was a positive association between *chronic respiratory disease* mortality, excluding respiratory cancers, and internal dose equivalent. An independent study of the same population reported positive trends for both *acute and chronic respiratory disease* illness. Acute respiratory illness includes influenza and pneumonia; chronic illnesses include emphysema and bronchitis. Hourly males had higher rates for *motor vehicle accidents*.

The Fernald study will be updated with new deaths through 1997. It will also include additional workers as well as an in-depth assessment of radiation, chemical exposures, and cigarette smoking.

Hanford Site *(Reference prefix - HAN)*

The Hanford Site produced reactor fuel, operated nine reactors and five chemical separation facilities, and fabricated plutonium components for the weapons program. Hanford site workers have been the subjects of more than 15 mortality studies beginning in 1964. The first study compared *longevity* of workers with that of their brothers and sisters. No differences were seen among radiation exposed and non-exposed workers in the average age at death.

A. Cancer Causes of Death -- Within Washington state for the period 1950-1971, atomic workers, presumed to be Hanford site workers, were reported to have higher proportions of death due to *multiple myeloma, cancer of the pancreas,* *and cancer of the colon* than were seen in the general population of Washington. A similar proportional analysis that included the average lifetime occupational dose of ionizing radiation found that the dose was higher than expected for *multiple myeloma, cancer of the pancreas, cancer of the brain and central nervous system, kidney cancer, lung cancer, colon cancer, myeloid leukemia and lymphoma*. In addition to the specific cancers, three broad categories: "*all cancer combined,*" "*bone marrow cancers,*" and "*reticuloendothelial cancers*" were identified as radiation sensitive cancers. This method of analysis was questioned because it included only deceased workers in the comparison group. Several independent reviewers of the average lifetime dose methodology concluded that the method was inappropriate although the data did support a conclusion that radiation was associated with *cancer of the pancreas* and *multiple myeloma.*

The earliest cohort studies reported on about 13,000 white males who were employed two or more years at Hanford with deaths through 1974, 1977 and 1978. Gradually the study population increased to include all workers without regard to length of employment at Hanford, about 44,000 employees with deaths through 1981 and 1986. Unmonitored (for radiation) males had higher death rates compared to the U.S. general population rates through 1986 *for cancer of the pancreas* and *miscellaneous solid tumors*.

In the early 1980s white males with a lifetime occupational dose of 20 mSv or more were known to have a small excess risk of lung cancer. A study of **tobacco use** in this group determined that the excess could not explained by smoking cigarettes.

Positive trends in the death rate with increasing exposure have been reported for white males and for white males and females combined. These trends were for deaths due to *cancer of the liver, cancer of the pancreas, Hodgkin's disease*, and *multiple myeloma.* In one study a positive trend for *female genital cancers* was noted.

Estimates of the increased **risk of death per unit radiation exposure** were made to test whether or not the radiation protection standards of the past adequately protected workers. One approach was to look at the upper limit of the risk per unit radiation and compare it to that for other populations. The absolute excess risk for leukemia per million person-years per 10 mSv, based on atomic bomb survivor data, as calculated by ICRP and BEIR committees, is approximately 1-2 deaths. For Hanford, the 95% upper confidence limit is about 4-5 deaths.

Age-at-exposure effect. The idea of sensitive age-at -exposure groups first appeared in 1977. Examination of the average lifetime dose equivalent for specific cancers compared to non-cancer deaths supported two sensitive age-at-exposure groups; under age 25 years and over age 45 years. Three subsequent analyses by the same research team reported this age sensitivity. It was variously reported as over age 58 years, over age 62 years, and age 55-65 years. A recent analysis reported a significant positive trend for all cancer combined by level of cumulative dose equivalent for monitored workers age 75 years and older who were born before 1905. A special case-control study of multiple myeloma at four DOE facilities reported that the most sensitive age-at-exposure group was age 45 years and older.

From 1981 through 1993 a number of models were proposed to estimate the proportion of cancers among Hanford workers that could be attributed to ionizing radiation. The attributable proportions for all cancers combined ranged from 5% to 50% depending on the statistical model used.

B. Non Cancer Causes of Death --- The earliest cohort studies reported on about 13,000 white males who were employed two or more years at Hanford with deaths through 1974, 1977 and 1978. Gradually the study population increased to include all workers without regard to length of employment at Hanford, about 44,000 employees with deaths through 1981 and 1986. Among female workers not monitored for external radiation, the rates for *accidents, poisonings, and violence* are greater than expected. Radiation-monitored females had a higher rate of death from diseases of the *musculoskeletal system and connective tissues* than expected.

Analyses included occasional search for positive trends among the non cancer causes of death. For deaths through 1986 no positive trends were detected for all noncancers combined, circulatory diseases, respiratory diseases excluding pneumonia, and external causes of death.

Lawrence Livermore National Laboratory *(Reference prefix - LLNL)*

Lawrence Livermore National Laboratory (LLNL) is a multi-purpose laboratory that conducts research and development for the weapons program and for stockpile stewardship.

A. Cancer Causes of Death --The incidence rate of *malignant melanoma* was higher for 5,100 LLNL employees than for the population of the region based on 19 cases diagnosed from 1972-77. Work involving exposure to ionizing radiation was not associated with a diagnosis of melanoma; working as a chemist was. In 1984, based on a review of records for persons with and without melanoma, occupational factors were reaffirmed as being associated with melanoma risk. Later, when the incidence rates for LLNL workers were recalculated for the period 1969-80, higher rates were found for some cancers in addition to malignant melanoma. The incidence rates for *salivary gland cancer* and rectal *cancer*, among female Laboratory workers, were above the rates for the region.

For male laboratory workers, *other nervous system tumors*, excluding brain tumors, were higher than expected.

Thirty one laboratory workers with malignant melanoma and a control group were interviewed about personal and occupational factors that might be associated with the disease. Five factors were more common than expected among persons with malignant melanoma. These were judged to contribute independently to a persons risk of melanoma. They were exposure to radioactive materials, work at Site 300, exposure to volatile photographic chemicals, participant at the Pacific Test Site, and chemist duties. The most recent interview study of 69 cases and an equal number of controls found that differences in personal factors, genetics, and recreational use of the outdoors were consistent with what is known about malignant melanoma of the skin. Only occupational exposure to alcohols, out of 39 industrial exposures examined, was more common among persons with melanoma.

Several special studies of the microscopic features of the melanoma tumors indicated that the tumor thickness among laboratory workers was significantly less than for individuals that did not work at LLNL, at least up to the time when the concern became public in 1977. These data on microscopic features were taken as evidence of medical over diagnosis of tumors at LLNL. A greater proportion of workers hired before 1962, who were engineers, particularly electrical engineers, had dark moles or pigmented nevi that are associated with a high risk of malignant melanoma.

B. Non Cancer Illness -- The studies did not consider non-cancers.

Linde Air Products *(Reference prefix - LIND)*

Linde Air Products in Buffalo, New York processed the highest grade Belgian Congo pitchblende and domestic uranium ores into uranium compounds from 1943 through 1949. Of the 995 employees studied, 699 worked in the facility for less than two years. Mortality rates through 1979 for the 995 white males studied were compared to U.S. rates and regional mortality rates. The results for the U.S. and region were similar.

A. Cancer Causes of Death -- a statistically significantly elevated laryngeal cancer rate was observed. Although smoking and alcohol use are known risk factors for laryngeal cancer, insufficient information on these factors was available to assess their potential contribution to these five deaths.

B. Non Cancer Causes of Death -- studies on former worker limited to white males to 1979 found an elevated SMR for diseases of the circulatory system, the primary contributor was arteriosclerotic heart disease; diseases of the respiratory system were elevated with pneumonia being the primary contributor. Smoking history was not available to further study disease risks for the cardiovascular and respiratory systems.

Los Alamos National Laboratory *(Reference prefix - LANL)*

Los Alamos National Laboratory (LANL) is a multi-purpose laboratory where nuclear weapons were designed, developed and tested; and small quantities of plutonium metal were produced. The first and longest running study at LANL was for two groups of workers with the highest exposures to plutonium. The two groups are 224 white males within the Manhattan Project and 26 workers with plutonium depositions in 1944-45. Deaths rates have been analyzed at various points in time. The study of 224 males reported that no death rate was greater than expected for deaths through 1980. For the 26 workers, the overall mortality rate and all causes of cancer rate were below what was expected based on the U.S. general population through 1987. In the most recent LANL study, based on 15,727 white males, no cause of death was higher than the U.S. rates through 1990.

A. Cancer Causes of Death -- Within the most recent LANL study, positive trends have been reported for external ionizing radiation and *cancers of the brain and central nervous system, cancer of the esophagus*, and *Hodgkin's disease*. Among workers not exposed to plutonium two additional positive trends were detected for *kidney cancer* and *lymphocytic leukemia*.

B. Non Cancer Causes of Death -- Among 6,970 LANL females, those classified as radiation workers had a high death rate for *suicide* through 1981. This was not related to duration of employment, plutonium exposure, or marital status.

C. Cancer Illness -- A special study of malignant melanoma cases between 1969 and 1978 revealed that the rate of newly diagnosed melanomas was similar to that for New Mexico in general. Detailed review of work histories for 15 cases did not reveal any important characteristics of workplace exposures that differed from a comparison group.

The **Los Alamos Zia Company** was the construction contractor at LANL. The Zia study included 5,424 workers who were monitored for exposure to either plutonium or external ionizing radiation.

A. Cancer Causes of Death -- For all Zia workers combined, the mortality rates through 1984 were greater than the U.S. rates for *stomach cancer*. Non-Hispanic males had higher rates for deaths from *all cancers and lung cancer*. No cause of death was reported with a positive trend for radiation exposure in the Zia Company study group.

B. Non Cancer Causes of Death -- For all Zia workers combined, *senility and ill-defined conditions, all injuries, all accidents*, and in particular, *motor vehicle* accidents were elevated. Non-Hispanic males had higher rates for deaths from *all causes, all circulatory diseases, and non cancerous respiratory diseases*. Hispanic males did not share the high rate for senility and ill-defined conditions

Mallinckrodt Chemical Works *(Reference prefix - MCW)*

The Uranium Division of Mallinckrodt Chemical Works (MCW) processed uranium ore and concentrate to pure uranium oxide and uranium metal from 1942 to 1966. The MCW study included deaths through 1993 for 2,514 white male employees.

A. Cancer Causes of Death -- No cancer causes of death were elevated relative to the U.S. general population and a positive trend was found for *kidney cancer* by level of exposure to cumulative external radiation.

B. Non Cancer Causes of Death -- There were no elevated death rates relative to the U.S. general population.

Mound Facility *(Reference prefix - MND)*

Mound was the site for the development of non-nuclear and nuclear components for weapons using polonium and beryllium, and for recycling tritium. Mound also produced plutonium-238 electric generators for spacecraft. Three mortality studies of white males have been conducted at Mound.

A. Cancer Causes of Death -- A preliminary analysis of mortality for 4,697 white male employees of the Mound Facility through 1979 found that among men first hired between 1943 and 1945, the rate for *all cancers combined* was elevated primarily due to *cancers of the rectum and lung.* The highest rate for lung cancer was for men who worked less than two years at Mound. Among men hired between 1943 and 1959, a period during which polonium-210 was processed, *cancer of the prostate* was elevated among men who worked more than 5 years. Reanalysis of the cohort using deaths through 1983, for 4,402 white males, confirmed that the rates for *all cancers combined, cancer of the lung,* and *cancer of the rectum* were elevated only among workers hired in the period 1944 through 1945 (World War II hires). The higher death rates in World War II hires did not appear to be due to radiation exposure.

   Workers monitored for external exposure to ionizing radiation had a positive trend for *cancer of the lymphopoietic and hematopoietic system* due primarily to the individual positive trends for *all leukemia combined*, particularly for *lymphatic and myeloid leukemia*. Males monitored for polonium-210 exposure did not reveal any positive trends for cancer.

B. Non Cancer Causes of Death -- Among men first hired between 1943 and 1945, the rates for *all respiratory diseases* and *all injuries* were higher than expected for deaths occurring through 1979.

Oak Ridge Reservation - Combined *(Reference prefix - ORC)*

Oak Ridge Reservation (ORR combined). There have been several studies that considered Oak Ridge workers as a single entity. The first study looked at the mortality experience of 28,008 white male World War II workers employed at three ORR facilities.

A. Cancer Causes of Death -- Compared to the rates for the U.S. population through 1980, the workers had a higher rate for *lung cancer*. When the study was updated with deaths through 1984, lung cancer was not elevated. The authors reported that there were substantial differences in death rates among workers at the various Oak Ridge facilities, particularly the rates for lung cancer, leukemia and other lymphatic cancer that are discussed below.

   In the updated study, data for 28,374 workers who were employed only at X-10 and Y-12 were analyzed for trends. Positive trends were reported with increasing external radiation dose for *all cancers combined*.

   There have been three published studies of **brain cancer** across the four ORR facilities. Of 26 chemicals included in the exposure analysis, none were positively associated with brain cancer. There were no positive trends for brain cancer with increasing external radiation dose and internal dose as measured by the lung dose. Although workers with *brain cancer* were more likely than other workers to have worked at ORR more than 20 years, there was no trend with years worked. A medical history of epilepsy or head injury was not associated with brain cancer.

   Mortality data through 1974 and through 1989 were analyzed for about 1,059 white male **welders** at the Oak Ridge Reservation. When deaths through 1989 were considered, welders had elevated rates for *lung cancer* and *cancer of the prostate*. The risk of each cause was different among the facilities. The risk of lung cancer among welders exposed to nickel oxides did not differ from non-exposed welders.

B. Non Cancer Causes of Death -- Compared to the rates for the U.S. population through 1980, the workers had higher rates for *tuberculosis; mental, psychoneurotic, and personality disorders; cerebrovascular disease; diseases of the respiratory system*, particularly *emphysema;* and *all accidents*, particularly *motor vehicle accidents.* Because these workers were not engaged in military service during wartime, it is not possible to know whether or not these conditions reflect occupational exposures or underlying health conditions that would have excluded them from military service.

Special studies of 1,059 Oak Ridge **welders** examined their mortality through 1989. Male welders had an elevated mortality rate for *gastric ulcers*.

Oak Ridge National Laboratory *(Reference prefix - ORX).*

The Oak Ridge National Laboratory (ORNL) is a multi-purpose laboratory that was involved in reactor operations, chemical separations, and research.

A. Cancer Causes of Death -- The first cohort study of ORNL considered 8,375 white males and deaths through 1977. No cancer cause of death was greater than expected based on the U.S. general population. A follow up study reported that the death rate from *leukemia* was greater than the U.S. rate through 1984, particularly among workers monitored for internal radiation contamination. In the most recent update with death rates through 1990, none of the three categories of cancer deaths reported -- all cancers combined, lung cancer, and leukemia, were elevated.

   Although the *leukemia* rate through 1984 was elevated, there was no positive trend in the death rate by level of cumulative external ionizing radiation dose. A positive trend was reported for *all cancers combined* by level of cumulative external dose. The most recent update, with deaths through 1990, did not find a trend for all cancers combined but did report that radiation doses received after age 45 years predicts the *all cancers combined* mortality rate.

B. Non Cancer Causes of Death -- There were no elevated rates for non cancer causes of death.

Oak Ridge Y-12 Plant *(Reference prefix - ORY).*

Y-12 was involved in uranium enrichment and fabrication of nuclear weapons components. The original Y-12 mortality study was updated twice. The first study included 18,869 white males who ever worked at the plant and mortality through 1974. The second study was restricted to 6,781 men who worked at least 30 days with mortality through 1979. The most recent study was expanded to include 10,597 nonwhite workers and females with deaths through 1990.

A. Cancer Causes of Death -- The death rate for *lung cancer* was higher than the U.S. rate in the two most recent studies with deaths through 1979 and 1990. An elevated *lung cancer* death rate was first evident for deaths occurring between 1955 and 1964. The rate continued to increase for deaths occurring between 1975 and 1979 followed by a declining rate.

Analysis of deaths through 1979 did not reveal positive trends for any cause of death with either external or internal exposure to ionizing radiation. The most recent study did not include radiation measurements.

Between 1953 and 1963 the Y-12 Plant used **metallic mercury** in a process to produce large quantities of enriched lithium. There were 5,663 workers categorized by exposure based on results of urinalysis data. Analysis of deaths through 1978 revealed no differences in the cancer mortality patterns for mercury exposed workers as a whole, workers with the highest mercury exposures, and workers employed more than a year in a mercury process.

During the early operation of the Y-12 plant from 1942-1947, a group of 694 male workers was exposed to **phosgene gas** on a chronic basis and 106 males received acute exposures along with 91 females. A control group of 9,280 workers who also worked at Y-12 during the same era, but who did not have phosgene exposure, was also described. All groups were followed through the end of 1978 with particular interest in respiratory diseases and lung cancer. There was no evidence for increased mortality from lung cancer in this group.

B. Non Cancer Causes of Death -- Studies of mercury exposed workers did not detect elevated mortality rates for non cancer causes of death. Studies of workers exposed to phosgene did not find elevated rates for non cancer respiratory disease.

C. Non Cancer Illness -- Between 1953 and 1963 the Y-12 Plant used **metallic mercury** in a process to produce large quantities of enriched lithium. There were 5,663 workers categorized by exposure based on results of urinalysis data. There were 502 mercury workers involved in a clinical study. Clinical measurements revealed some *deficiencies in neurological function* particularly among those workers with the highest exposures, but not with the duration of exposure. A follow up study of 219 of the original subjects in the 1990s revealed that some neurologic effects were still detectable.

Oak Ridge K-25 Gaseous Diffusion Plant *(Reference prefix - ORK).*

The K-25 plant was a center for uranium enrichment for nuclear weapons and commercial uranium fuel. The death rates through 1989 for 35,712 workers were the focus of the study.

A. Cancer Causes of Death -- White male workers had high rates relative to U.S. general population rates for *cancer of the respiratory system*, particularly *lung cancer* and *bone cancer.*

Powdered nickel was used at the Oak Ridge K-25 gaseous diffusion plant in the production of the barrier material used to separate and enrich uranium. Death rates for 814 nickel workers who fabricated the barriers were compared to 1,600 controls. There were no differences in the death rates for the exposed and non exposed workers by cause of death through 1972. A later study compared the mortality through 1977 of the nickel workers and 7,552 non exposed workers. There was no cancer cause of death with a rate higher than the U.S. rate and no differences in the rates for exposed and non exposed workers.

B. Non Cancer Causes of Death -- White male workers had high rates relative to U.S. general population for: *mental disorders, all respiratory diseases*, particularly *pneumonia; symptoms, senility, and ill-defined conditions; all external causes of death*, particularly *accidents* and specifically *motor vehicle accidents*. White females had high rates for *symptoms, senility, and ill-defined conditions*. Nickel exposed workers did not have elevated rates for non cancer causes of death.

C. Cancer Illness -- Epoxy resins and solvents were common exposures among K-25 gas centrifuge workers. A total of 263 workers with the most exposure were compared with 271 employees with no exposure at the plant during the same time period. The centrifuge workers reported five incident *bladder cancers* versus none reported by the non-centrifuge group. One of the epoxy resins was a potential bladder carcinogen. None of the workers with bladder cancer had jobs that required routine, hands-on work with that material.

Pantex Plant *(Reference prefix - PTX)*

Pantex is the center for high-explosives component fabrication for nuclear weapons and for nuclear weapons disassembly and storage. The cohort mortality study of the Pantex Plant included mortality through 1978 among 3,564 white male employees. There were no cancer or non cancer causes of death with rates greater than those seen in the U.S. general population.

Portsmouth Gaseous Diffusion Plant *(Reference prefix - PTS)*

The Portsmouth Gaseous Diffusion Plant is dedicated to enriching natural uranium in the uranium-235 isotope for nuclear reactors and weapons uses. The activities and processes are similar to those at the Paducah Gaseous Diffusion Plant in Kentucky.

A. Cancer Causes of Death -- Mortality among 5,733 white male employees at the Portsmouth Gaseous Diffusion Plant was studied through 1982. This study was expanded to include all 8,877 workers employed through 1991. No cancer death rate was greater than expected based on the U.S. general population rates for either study.

Among the 6,827 workers exposed to uranium hexafluoride, special emphasis was on the death rates for all cancers combined, stomach cancer, hematopoietic cancer, and lung cancer. The rate for each of these was no larger than the comparable U.S. rate. There were no positive trends for these four cause of death groups by increasing urine counts. Among 1,446 workers exposed to fluorine or fluoride, and 465 exposed to nickel; the rate for all cancers combined did not exceed the U.S. rates.

B. Non Cancer Causes of Death -- No non cancer cause of death had a rate higher than the U.S. general population rate.

Rocketdyne/Atomics International *(Reference prefix - RAI)*

Rocketdyne/Atomics International was involved in small experimental reactor design, construction, operation and decommissioning. The Rocketdyne/Atomics International Radiation Study included 4,563 employees in the health physics monitoring program from 1950 through 1993 with records. The mortality study considered external exposure to ionizing radiation and internal deposition of radioactive materials.

A. Cancer Causes of Death -- Compared to U.S. general population through 1994, no rate for a cancer cause of death was greater than expected rate based on the U.S. general population.

   Positive trends in the rates by level of exposure to external radiation were reported for three of the four cancer categories examined: *all cancers combined*, *cancers of the blood and blood forming tissues*, and *lung cancer*. In the Rocketdyne/Atomics International Chemical Study no relationship was seen between asbestos exposure and *lung cancer* mortality among the radiation-monitored workers.

   Positive trends in the rates by level of internal radiation dose were reported for *cancers of the blood and blood forming tissues*, and *cancers of the upper-aerodigestive-tract* (oral cavity, pharynx, esophagus, and stomach).

B. Non Cancer Causes of Death -- There were no reported elevated non cancer mortality rates for this cohort.

Rocky Flats *(Reference prefix - RFP)*

Rocky Flats Plant was established in 1952 to produce plutonium parts for nuclear weapons as well as other uranium, beryllium, and steel weapons components.

A. Cancer Causes of Death -- There were no cancer causes of death that were higher than the U.S. general population rates through 1979. Workers with a higher body burden (internal deposition) of plutonium had a higher rate for all *lymphopoietic* cancers combined when compared to those with a smaller body burden.

   There were no positive trends for any cancer cause of death by level of external or internal radiation exposure.

B. Non Cancer Causes of Death -- For the 7,112 white males who ever worked at Rocky Flats, only the death rate for *benign and unspecified neoplasm of the brain* was greater than the corresponding U.S. general population rate. Among the 5,413 Rocky Flats white males who worked at the site for at least 2 years, there was a higher rate of *benign tumors and tumors of unspecified nature* when comparing them with the U.S. general population through 1979; these were brain tumors. A study of 16 of the 22 known brain tumor cases through 1977 found no associations with exposure to internally deposited plutonium, external ionizing radiation or occupation. Independent review of occupational dosimetry records and pathologic examination of tissues from six of these workers led to the conclusion that none were radiation-related.

   A subsequent reanalysis of the data for the 5,413 Rocky Flats workers found a positive trend for *all non-cancers* across external exposure groups due to a strong positive trend for *circulatory diseases*.

Savannah River Site *(Reference prefix - SRS)*

The Savannah River Site produced, purified and processed plutonium, tritium, and other radioisotopes for the nuclear weapons program.

A. Cancer Causes of Death -- The first complete mortality study included 9,860 white male Savannah River workers. A higher rate of *leukemia* than the U.S. general population through 1980 was reported. This was concentrated among hourly workers employed before 1955 who worked from 5 to 15 years. Review of the plant records and job duties of all workers who died from leukemia indicated that seven, half of the leukemia deaths, had the potential for some exposure to industrial solvents. The *leukemia* death rate through 1986 was higher than expected only for those deaths occurring from 1965 through 1969. Preliminary findings from the most recent study of a larger group of workers reported that the leukemia mortality rate was not higher than the U.S. rate through 1995.

   A positive trend was seen for *leukemia* mortality and external dose for deaths through 1986.

B. Non Cancer Causes of Death -- There were no non cancer causes of death rates higher than the U.S. general population rates.

C. Cancer Illness -- Three cancer incidence studies were conducted among active workers beginning with new cancer cases diagnosed in 1956 and ending in 1974, 1980, and 1983 respectively. There were no overall cancer incidence rates or rates by radiation exposure group that were higher than U.S. rates. Special investigations were conducted for (1) leukemia, and later for (2) leukemia, prostate cancer, and lung cancer. Preliminary results from the later study indicate that radiation monitored workers in the higher exposed group had a higher death rate for *chronic lymphocytic leukemia* than expected.

Multi-Site study: All Department of Energy facilities (Greater than 5 rem Study) *(Reference - MULTI96)*

This is a study of 1,404 DOE and DOE contractor employees who received 50 mSv (5 rem) or more external radiation dose in any calendar year during employment at the facilities.

A. Cancer Causes of Death -- Within this special group of workers, rates for cancer causes of death were not higher than the corresponding U.S. general population rates.

B. Non Cancer Causes of Death -- Within this special group of workers, rates for non cancer causes of death were not higher than the corresponding U.S. general population rates.

Multi-Site study: Multiple Myeloma *(Reference - MULTI98b)*

The study included 98 cases of **multiple myeloma** and 391 controls from the populations of the Hanford Site, Los Alamos National Laboratory, Oak Ridge National Laboratory, and the Savannah River Plant. The risk of multiple myeloma was linked to external ionizing radiation exposure after age 45 years.

Multi-Site study: Uranium dust study *(Reference - MULTI95b)*

This special study of uranium dust exposure and **lung cancer** among workers employed between 1943 and 1947 was conducted at the Tennessee Eastman, Y-12, Fernald, and Mallinckrodt facilities. There were 787 cases of lung cancer in the study. The risk of lung cancer did not increase with increasing radiation dose. The authors did suggest that there was a trend in risk for worker exposure after age 45 years. Analysis by external radiation dose and exposure to thorium, radium, and radon were uninformative.

Multi-Site study: Uranium Millers *(Reference prefix - MULTI83)*

The front end of the uranium fuel cycle includes the milling of uranium ore. The most recent National Institute for Occupational Safety and Health study of uranium millers included 2,002 males from seven plants on the Colorado Plateau. These men worked at least one year since 1940 and had never worked in uranium mining.

A. Cancer Causes of Death -- There were no cancer causes of death with rates higher than the U.S. general population rates through 1977.

B. Non Cancer Causes of Death -- Compared to the U.S. population through 1977, there were two causes of death that had higher rates*: non malignant respiratory diseases*, particularly the chronic respiratory conditions, and *miscellaneous accidents*.

APPENDIX 4

TABLES OF

STANDARDIZED MORTALITY RATIOS

FROM EPIDEMOLOGIC STUDIES

Table 1. Rank Ordered Cause-Specific Standardized Mortality Ratios* (SMRs) for US Nuclear Weapons Workers

ALL CAUSES OF DEATH		INFECTIOUS AND PARASITIC DISEASES	Tuberculosis	ALL CANCERS		All cancer excluding leukemia	Buccal cavity and pharynx		Digestive organs and peritoneum		Esophagus	Stomach		Small intestines and colon	Colon		Rectum		Liver and gall bladder		Pancreas		Peritoneum and unspecified	Respiratory system	
133	82	136	104	*112*	86	*121*	410	*55*	163	*74*	307	366	61	82	204	63	250	25	403	51	378	71	31	161	81
121	82	122	91	110	86	99	292	49	131	*74*	175	*281*	59	78	173	62	150	1	387	44	277	70	22	144	80
118	82	97	90	110	86	91	278	48	126	74	146	234	58	68	128	*57*	139	1	347	35	238	68		139	76
109	81	91	56	106	*85*	85	236	48	123	73	140	180	57		124	56	130	0	211	16	190	66		136	76
106	*80*	90	52	105	85	85	200	48	119	73	138	169	56		117	*53*	109	0	193	0	*169*	65		136	75
104	*79*	86	35	104	85	78	196	45	112	73	130	*165*	54		116	51	108	0	171	0	*157*	65		132	*73*
103	79	84	*32*	103	85		182	44	107	72	125	165	48		116	2	103		164	0	143	61		131	*66*
102	75	80	*29*	103	85		148	43	106	*71*	123	*149*	47		111	1	103		156	0	136	59		129	65
102	*74*	78	4	103	84		144	40	104	68	115	128	46		106	1	101		149	0	132	59		127	65
101	*74*	77	4	102	83		140	32	104	68	115	126	44		101	1	98		145	0	130	56		*125*	62
101	74	72	1	102	*82*		132	*23*	102	67	104	118	40		98	0	91		145	0	128	55		*125*	*59*
101	74	71	0	101	*82*		115	*23*	98	67	101	118	30		96		90		139	0	127	50		*123*	59
100	*73*	67	0	100	81		113	22	98	66	100	107	2		95		85		128	0	124	43		*119*	57
98	*73*	*65*		100	81		109	*21*	96	65	96	104	1		95		74		123		118	38		*117*	*56*
97	*72*	63		100	80		108	*13*	92	65	95	94	0		92		72		112		115	26		*116*	56
97	*72*	60		99	80		106	1	91	64	94	93			90		72		110		109	25		116	50
96	*72*	60		99	*79*		99	0	90	63	94	92			89		68		110		108	*14*		115	*46*
95	*72*	49		98	*79*		97	0	89	63	93	91			89		67		109		107	2		115	45
95	*71*	*40*		98	*78*		94	0	88	62	93	90			88		66		105		106	1		113	36
95	*71*	40		96	*78*		93	0	88	62	92	86			87		66		103		106	1		113	20
95	71	39		96	78		87	0	87	62	89	84			87		61		101		104	0		112	
93	*69*	*38*		95	78		87		87	60	84	84			86		59		101		103			110	
92	*68*	38		95	*76*		82		86	60	84	83			84		*58*		97		101			108	
92	*68*	*37*		94	*75*		82		85	58	83	82			84		*55*		94		100			108	
92	*68*	36		94	*75*		82		85	58	*82*	82			84		54		92		97			107	
92	*68*	35		94	*75*		81		84	57	80	80			84		*53*		91		97			104	
91	*68*	*30*		92	75		80		83	55	80	79			82		53		91		97			103	
90	*67*	29		91	75		*79*		83	53	79	78			82		52		86		96			102	
90	67	28		91	*71*		79		83	49	74	78			*81*		47		85		96			101	
90	*65*	28		91	*71*		79		83	43	69	77			*78*		46		82		95			98	
89	*64*	27		90	*70*		79		82	37	67	75			78		43		*78*		95			98	
89	*63*	27		90	70		76		82		60	*73*			78		43		75		93			97	
88	*63*	25		*89*	*69*		75		*81*		58	72			74		43		71		92			97	
88	*63*	23		88	69		74		81		56	72			*73*		*42*		69		91			94	
87	*62*	*22*		88	*64*		73		81		50	*70*			73		41		68		91			93	
86	*62*	12		88	64		73		81		49	69			*71*		40		68		89			93	
86	*60*	2		88	64		72		*80*		*41*	68			71		*39*		64		89			92	
86	*56*	0		87	*60*		70		80		0	68			70		38		64		88			88	
86	*54*			87	58		69		80		0	66			69		34		64		85			88	
85	*49*			*86*	54		66		*79*		0	64			67		*33*		61		84			84	
84	*36*			*86*	28		63		76		0	63			64		33		61		82			83	
83				86	3		56		75		0	62			63		30		*53*		81			83	

- **SMR values greater than 100 indicate mortality rates above the general population rate; values below 100 indicate rates below the general population rates**. *Bold italicized* **SMRs indicate those that are statistically significant or "truly" greater than or less than the general population rate.**
- **The symbols \ · \ · · denote sub categories of the preceding cause of death category.**

Table 1. Rank Ordered Cause-Specific Standardized Mortality Ratios* (SMRs) for US Nuclear Weapons Workers

·Larynx	·Trachea, bronchus and lung		Bone, connective tissue, skin and breast	·Bone		·Skin		·Female breast	Genitourinary organs	·All female genital organs	· All uterus	· Cervix uteri	· Other uterus	· Ovary and other female genital organs	·All male genital organs	· Prostate		· Testis and other male genital organs	· ·Testis	·Bladder and other urinary organs	· Bladder		· Other and unspecified urinary organs		· Kidney	Other and unspecified sites
447	190	96	260	1812	0	314	36	127	161	*87*	100	110	95	*79*	27	202	60	173	144	169	233	1	269	40	104	94
236	166	94	54	307	0	170	28	121	63	*70*	99	88	80	89	19	*195*	3	112	82	116	187	0	205	39	100	69
199	161	92		*191*	0	228	24	121		36	95	0	0	102		186	0	93	71	100	134	0	166	31		89
169	152	92		*182*	0	184	1	118		36	80			89		152		91	71	0	130	0	165	0		71
166	150	92		168	0	162	0	104			64			78		142		90	64		124		150	0		
164	142	89		162	0	161	0	95			63			75		140		86	63		113		139	0		
161	138	88		119	0	144	0	92			34			64		135		73			104		134	0		
161	137	85		117	0	132	0	91			33			*38*		133		72			100		131	0		
155	*136*	84		115	0	128		89			0					*132*		70			98		130	0		
136	136	84		113	0	126		88								131		58			93		128	0		
134	136	83		109	0	125		*86*								127		23			89		126			
131	135	83		108	0	125		85								120		0			86		122			
119	*134*	81		106	0	122		*55*								118		0			85		122			
106	134	80		105	0	121										116		0			84		121			
106	130	*78*		104	0	117										112					82		120			
100	*127*	78		94	0	116										109					76		114			
97	127	78		89	0	107										106					*76*		112			
96	126	*77*		87	0	106										105					75		108			
88	*125*	*75*		78		103										104					72		103			
86	*124*	*75*		77		102										104					72		101			
82	122	75		74		99										102					69		100			
75	*120*	*72*		73		97										101					68		99			
74	*119*	67		62		97										100					67		97			
70	119	*65*		51		96										100					67		95			
69	119	65		44		95										100					65		95			
68	*118*	*64*		32		95										100					62		*95*			
67	*118*	*62*		31		94										99					*60*		94			
63	117	*62*		1		92										96					60		93			
60	113	*61*		1		90										95					59		92			
52	113	60		0		86										94					59		89			
32	113	60		0		86										92					59		84			
0	111	58		0		86										92					57		72			
0	109	58		0		84										90					56		72			
0	108	57		0		84										83					56		70			
0	108	*55*		0		80										79					55		67			
	108	*49*		0		77										73					52		63			
	103	*45*		0		76										71					43		63			
	101	39		0		75										69					43		62			
	100	14		0		66										68					42		60			
	99	1		0		65										*67*					36		*59*			
	97	1		0		48										67					1		56			
	97	0		0		40										66					1		51			
	97															64										

- **SMR values greater than 100 indicate mortality rates above the general population rate; values below 100 indicate rates below the general population rates**. *Bold italicized* **SMRs indicate those that are statistically significant or "truly" greater than or less than the general population rate.**
- **The symbols · · · denote sub categories of the preceding cause of death category.**

Table 1. Rank Ordered Cause-Specific Standardized Mortality Ratios* (SMRs) for US Nuclear Weapons Workers

Eye	Brain and other nervous system		Thyroid	All other solid tumors	All lymphatic and hematopoietic cancer		Lymphopoietic cancer	Lymphosarcoma and reticulosarcoma		Hodgkin disease		Other lymphoid tissue	Multiple myeloma	Leukemia and aleukemia		Lymphatic leukemia	Other lymphatic and hematopoietic	Other lymphatic and hematopoietic	Other hematopoietic and lymphatic	Other unspecified cancer	BENIGN AND UNSPECIFIED NEOPLASMS		ENDOCRINE, METABOLIC, NUTRITIONAL	Diabetes mellitus	BLOOD AND BLOOD-FORMING ORGANS
244	230	75	1317	*156*	237	83	182	571	27	1286	56	116	133	*223*	82	125	221	150	133	134	*600*	0	213	250	285
193	209	74	428	*147*	156	82	101	321	25	231	*41*	41	129	*163*	79		213	118		81	*405*	0	124	196	148
180	188	72	412	107	146	80	83	170	21	200	31	36	93	163	77		186	102		43	390	0	98	106	123
170	182	69	370	104	146	79		165	2	191	0	19	91	160	77		146	99		41	*376*	0	94	76	119
143	180	69	236	103	142	79		163	1	154	0		83	159	76		141	98			371	0	91	69	116
114	165	68	196	102	141	77		157	0	145			55	155	75		136	97			263	0	88	*67*	103
99	160	68	174	100	125	77		148		143			4	148	75		134	92			250		86	66	99
97	157	66	157	90	125	76		137		138				146	74		133	91			201		85	63	99
0	154	60	134	81	123	73		129		138				135	72		132	87			190		84	62	94
0	149	59	119	80	123	71		115		128				134	71		132	85			135		83	*61*	90
0	147	55	83	53	121	71		112		126				132	71		129	83			133		76	58	88
0	136	53	75		120	69		106		123				129	65		128	78			122		*69*	*55*	85
0	131	52	61		119	69		106		110				129	60		126	70			110		67	55	84
0	129	45	52		112	66		105		103				128	60		123	64			102		65	55	79
0	128	37	49		111	64		105		103				124	58		118	59			100		64	52	76
0	122	36	47		110	59		104		98				121	57		113	49			*98*		*62*	38	76
0	122	34	44		106	56		98		94				118	56		110				92		62	*24*	75
0	119	25	39		106	51		95		94				117	54		110				92		*56*	1	69
0	119	23	*33*		105	30		94		93				116	50		106				90		52	1	65
0	119	1	0		102			93		91				115	46		105				87		52	1	63
0	117	0	0		101			92		91				113	41		98				87		52		59
0	116	0	0		100			91		90				112	*20*		98				84		*51*		56
0	114	0	0		99			87		90				111	1		97				79		19		*52*
0	114	0	0		98			85		87				110	0		95				75		1		53
0	112		0		98			82		86				108	0		90				74				49
0	111		0		96			80		86				107	0		84				74				42
	109		0		95			78		84				107	0		84				66				41
	109		0		94			77		83				106			83				58				34
	108		0		93			76		83				105			81				56				0
	106		0		93			71		78				101			77				55				0
	104		0		92			69		77				101			77				55				0
	102		0		91			62		74				98			71				54				
	96		0		90			62		74				94			68				54				
	96		0		90			55		72				91			57				52				
	96		0		89			54		69				91			53				*49*				
	95		0		87			53		62				87			2				40				
	93		0		87			50		62				84			0				39				
	87				86			45		62				84							37				
	86				85			43		60				84							32				
	80				85			39		60				83							25				
	78				*84*			*38*		59				83							1				
	78				83			37		57				82							0				

- **SMR values greater than 100 indicate mortality rates above the general population rate; values below 100 indicate rates below the general population rates**. *Bold italicized* **SMRs indicate those that are statistically significant or "truly" greater than or less than the general population rate.**
- **The symbols ∖ · ∖ · · denote sub categories of the preceding cause of death category.**

Table 1. Rank Ordered Cause-Specific Standardized Mortality Ratios* (SMRs) for US Nuclear Weapons Workers

MENTAL DISORDERS	NERVOUS SYSTEM AND SENSE ORGANS	CIRCULATORY SYSTEM		·Chronic rheumatic heart disease	·Ischemic and other heart disease	· ·Ischemic heart disease	·Cerebrovascular disease	RESPIRATORY SYSTEM		·Pneumonia	·Emphysema	·Asthma	DIGESTIVE SYSTEM		·Ulcer of stomach	·Cirrhosis	GENITOURINARY SYSTEM		·Nephritis and nephrosis	· ·Chronic nephritis	SKIN AND SUBCUTANEOUS TISSUE	MUSCULOSKETAL AND CONNECTIVE TISSUE	SYMPTOMS AND ILL-DEFINED CONDITIONS	
1232	**570**	*118*	*76*	**210**	*383*	*119*	**199**	**266**	**83**	**316**	**193**	**177**	**163**	*60*	**201**	**355**	**155**	*54*	*32*	*318*	**313**	*233*	*593*	**1**
384	**155**	**106**	*76*	**100**	*92*	**108**	**155**	*152*	**83**	*217*	**148**	**125**	**108**	*59*	**90**	**102**	**132**	**54**	**60**	**218**	**241**	*206*	**581**	**0**
306	**108**	**102**	*73*	**96**	*79*	**101**	**135**	**134**	**82**	**133**	**127**	**107**	**106**	**58**	**69**	**91**	**130**	**54**	**0**	**121**	**127**	*138*	*402*	**0**
180	**102**	**100**	*72*	**89**	*74*	**92**	**119**	**133**	**81**	*122*	*120*	**86**	**106**	*57*	**50**	**79**	**127**	**52**		**104**	**107**	**130**	*330*	
164	**93**	**99**	*70*	**64**	**39**	**91**	*110*	**128**	**80**	*117*	**115**	**77**	**106**	*57*	**50**	*74*	**126**	*42*		**99**	**79**	**130**	*325*	
159	**90**	**98**	*70*	**57**		**89**	**100**	**128**	**78**	**117**	**112**	**0**	**105**	*54*	**50**	**72**	**118**	*39*		**97**	**62**	**121**	*325*	
148	**86**	**97**	*70*	**54**		**89**	**93**	*126*	**78**	**112**	**111**	**0**	**103**	*54*		**70**	**111**	**21**		**87**	**49**	**118**	*323*	
147	**86**	**96**	**70**	*33*		**88**	**93**	*119*	**77**	**111**	**109**	**0**	**102**	*54*		*65*	**100**	**19**		**83**	**27**	**105**	*319*	
143	**84**	*95*	**69**	*24*		*77*	**92**	**119**	*76*	**105**	**100**	**0**	**98**	**54**		*60*	**99**	**19**		**73**	**23**	**94**	*301*	
141	**84**	*93*	*68*	*22*		*75*	**92**	**116**	**76**	**104**	**88**	**0**	**97**	*52*		*58*	**93**	**1**		**72**	**16**	**93**	*293*	
131	**82**	**93**	*68*	*22*		**75**	**91**	**113**	**76**	**99**	**71**	**0**	**93**	*46*		**54**	**93**	**1**		**60**	**0**	**88**	*289*	
121	**82**	**92**	*65*			*66*	**90**	**113**	**76**	**99**	*68*	**0**	**91**	**45**		*49*	**91**	**0**		**55**	**0**	**71**	*262*	
116	**81**	**92**	**65**			*61*	**88**	*112*	**75**	**98**	**67**		**89**	**43**		*45*	**90**	**0**		**52**	**0**	**49**	*249*	
113	**81**	*90*	**65**			*58*	**87**	**112**	**75**	**83**	**65**		**86**	*42*		*35*	**89**	**0**		**48**	**0**	**46**	*234*	
113	**74**	*90*	**64**			*32*	**85**	**111**	*74*	**83**	**61**		*85*	*41*		*31*	**86**	**0**		**41**	**0**	**37**	*227*	
102	**73**	**90**	*63*				*81*	**111**	*69*	**82**	**52**		*84*	*40*			**84**			*37*	**0**	**29**	*227*	
95	**73**	*89*	*62*				**81**	**109**	*65*	*70*	*39*		*83*	**35**			*83*			**0**	**0**	**23**	**204**	
89	**72**	**89**	*62*				**78**	**107**	*63*	**54**	*20*		**83**	*34*			**82**			**0**	**0**		**161**	
82	*70*	*88*	**61**				**74**	**105**	**62**	**38**	**4**		**82**	**6**			**81**			**0**	**0**		**160**	
82	**68**	*88*	**60**				*72*	**103**	*61*	*33*	**2**		*81*	**3**			**80**			**0**			**159**	
80	**66**	*88*	*57*				**71**	**101**	**60**	*12*	**1**		*80*	**3**			**80**			**0**			**144**	
76	**62**	**88**	**57**				**67**	**100**	**59**	**4**	**1**		*80*	**1**			**80**						**130**	
71	*61*	*87*	**56**				*63*	**96**	*57*	**3**	**0**		**80**				**78**						**105**	
70	*55*	**87**	*55*				*61*	**94**	*56*	**1**	**0**		**78**				**78**						**101**	
67	**52**	*86*	*45*				**58**	**93**	*55*	**1**			*76*				**72**						**99**	
56	**50**	**86**	*40*				*57*	**92**	*54*	**1**			**76**				**69**						**88**	
44	**47**	**85**	*38*					**92**	*46*				**76**				**69**						**80**	
42	*44*	*84*						**92**	**46**				*73*				**69**						**80**	
3	*43*	**84**						**91**	*42*				**73**				**65**						**63**	
2	*40*	*83*						**91**	*42*				*70*				*64*						**57**	
2	*37*	*83*						**90**	*42*				*70*				**64**						**52**	
2	*36*	**83**						**89**	*41*				**68**				*63*						**51**	
0	*26*	**83**						**88**	*40*				**67**				**61**						**49**	
0	**22**	*82*						**88**	*36*				**66**				*59*						**41**	
	1	**82**						**88**	*30*				**65**				**59**						*40*	
	1	**81**						**87**	**21**				**64**				**59**						**39**	
	0	*80*						**86**	*16*				*63*				**57**						*37*	
	0	**80**						**86**	**3**				**63**				**56**						**31**	
	0	*78*						**85**					*62*				**56**						**29**	
	0	**78**						**85**					**62**				*55*						**23**	
	0	**78**						**85**					**62**				**55**						*21*	
		78						**84**					**61**				**55**						**18**	

- **SMR values greater than 100 indicate mortality rates above the general population rate; values below 100 indicate rates below the general population rates**. *Bold italicized* **SMRs indicate those that are statistically significant or "truly" greater than or less than the general population rate.**
- **The symbols · ·· denote sub categories of the preceding cause of death category.**

Table 1. Rank Ordered Cause-Specific Standardized Mortality Ratios* (SMRs) for US Nuclear Weapons Workers

ACCIDENTS POISONINGS, AND VIOLENCE	·All external causes of death		· Unintentional injuries	·All accidents	· Motor vehicle accidents	·Suicide	·Violence
138	**201**	*72*	*68*	**241**	**480**	**159**	*44*
135	**162**	*72*	*59*	**184**	**334**	**157**	*41*
109	**153**	*66*		*133*	*170*	**122**	*36*
109	**152**	**66**		**123**	**159**	**105**	
109	*123*	*65*		*117*	**134**	**97**	
104	*119*	*63*		*112*	**127**	**97**	
100	*118*	*62*		**106**	*123*	**91**	
94	**118**	**62**		**100**	**120**	**90**	
90	**117**	*57*		**94**	**119**	**89**	
89	*116*	*53*		**92**	*118*	**87**	
82	**116**	*51*		**92**	**110**	**82**	
82	**113**	*45*		**91**	**104**	**81**	
75	*111*	**29**		**89**	**100**	**79**	
67	**108**	**0**		*88*	**90**	**78**	
65	**107**			**87**	*80*	**75**	
36	*105*			**86**	*77*	**74**	
	105			**86**	*77*	*65*	
	102			**85**	**77**	**65**	
	102			*80*	**71**	**60**	
	99			**80**	**66**	*27*	
	97			*78*	**61**	**2**	
	96			**75**	*60*	**1**	
	95			*73*	**0**	**0**	
	90			**67**			
	90			**65**			
	89			*60*			
	89			*54*			
	89			*53*			
	87			*51*			
	86			**50**			
	86			**4**			
	84			**4**			
	82			**0**			
	81						
	79						
	79						
	78						
	77						
	77						
	76						
	75						
	75						

- **SMR values greater than 100 indicate mortality rates above the general population rate; values below 100 indicate rates below the general population rates**. *Bold italicized* **SMRs indicate those that are statistically significant or "truly" greater than or less than the general population rate.**
- **The symbols \ · \ · · denote sub categories of the preceding cause of death category.**

Table 2-1. Statistically Significant Elevated Standardized Mortality Ratios (SMRs) by Type of Cancer and Facility for US Nuclear Weapons Workers*

SMR (1)	DOE site	Minimum days worked	Period of employment		Deaths Through	Race & sex	Subgroup (exposure)	Number of workers	Person-Years	Referen and publicat n year (2
RESPIRATORY SYSTEM - All										
125	Fernald	1	1951	1981	1989	W males	Hourly pay category	4,014	121,038	FMPC96
125	Oak Ridge	.	1943	1947	1979	W males	W males	28,008		ORC90
116	Oak Ridge	.	1954	1985	1984	W males	W males			ORC97a
123	Oak Ridge K25	.	1945	1984	1989	W males	Hourly pay category			ORK96
117	Oak Ridge K25	.	1945	1984	1989	W males	W males	35,712		ORK96
119	Oak Ridge Y12	.	1947	1974	1990	W males	W males	6,591		ORY96
RESPIRATORY SYSTEM - Larynx										
447	Linde Air Prod.	30	1943	1949	1979	W males	W males	995	27,740	LIND87
RESPIRATORY SYSTEM - Lung										
125	Fernald	1	1951	1981	1989	W males	Hourly pay category	4,014	121,038	FMPC96
127	Oak Ridge	.	1943	1947	1979	W males	W males	28,008		ORC90
118	Oak Ridge	.	1954	1985	1984	W males	W males			ORC97a
138	Oak Ridge	.	1943	1985	1989	W males	Welders	1,211		ORC98
124	Oak Ridge K25	.	1945	1984	1989	W males	Hourly pay category			ORK96
119	Oak Ridge K25	.	1945	1984	1989	W males	W males	35,712		ORK96
134	Oak Ridge Y12	120	1953	1963	1978	W males	Comparison (no mercury exposure)	3,260		ORY84
118	Oak Ridge Y12	2	1943	1945	1978	W males	Comparison (no phosgene exposure)	9,280	266,027	ORY85
136	Oak Ridge Y12	.	1947	1974	1979	W males	W males	6,781		ORY88b
120	Oak Ridge Y12	.	1947	1974	1990	W males	W males	6,591		ORY96
DIGESTIVE SYSTEM - Stomach										
281	Fernald	1	1951	1981	1989	W males	Salaried pay category	4,014	121,038	FMPC96
165	Los Alamos Zia	.	1946	1978	1984	W males	Monitored-external & Plutonium	4,942		LANL92
DIGESTIVE SYSTEM - Pancreas										
169	Hanford	.	1944	1978	1981	All males	Not monitored-external			HAN89
157	Hanford	.	1944	1978	1986	All males	Not monitored-external	3,400		HAN93a
Bone										
191	Oak Ridge K25	.	1945	1984	1989	W males	Hourly pay category			ORK96
182	Oak Ridge K25	.	1945	1984	1989	W males	W males	35,712		ORK96
Prostate										
233	Oak Ridge K25		1943	1985	1989	W male	Welders K25	683		ORC98
195	Oak Ridge		1943	1985	1989	W male	Welders	1,211		ORC98
Leukemia										
223	Oak Ridge X10	1	1943	1972	1984	W males	Monitored-internal	3,763		ORX91
163	Oak Ridge X10	1	1943	1972	1984	W males	Monitored-external	8,318		ORX91
ALL CANCER (excluding leukemia)										
121	Fernald	1	1951	1981	1989	W males	Hourly pay category	4,014	121,038	FMPC96

*** Source: Table derived from detailed listing of all statistically significant SMRs in Appendix 1 (Table 1). (1) SMR is the abbreviation for "Standardized Mortality Ratio." In this table, SMR values greater than 100 indicate a mortality rate "truly" greater than the general population rate. Column headings used here are an expanded version of the**

shorthand headings used in the detailed SMR tables. When no subgroups were given, the race and sex group is given for clarity. (2) References are listed in Appendix 2.

Table 2-2. Statistically Significant Elevated Standardized Mortality Ratios (SMRs) for Non-Cancers by Facility for US Nuclear Weapons Workers*

SMR(1)	DOE Site	Minimum days worked	Period of employment		Deaths through	Race & Sex	Subgroup (exposure)	Number of workers	Person-years	Reference and publication year (2)
BENIGN & UNSPECIFIED TUMORS										
600	Rocky Flats	730	1951	1977	1977	W males	Monitored-external (1+ rem)			RFP83b
405	Rocky Flats	730	1951	1977	1977	W males	Employed 2+ years			RFP83b
376	Rocky Flats	730	1952	1979	1979	W males	Employed 2+ years	5,413		RFP87
MENTAL DISORDERS										
164	Oak Ridge K25		1945	1984	1989	W males	Hourly pay category			ORK96
159	Oak Ridge K25		1945	1984	1989	W males	W males	35,712		0RK96
141	Oak Ridge Y12	2	1943	1945	1973	W males	Comparison workers (no phosgene)	9,352	240,494	ORY80
CIRCULATORY SYSTEM – All										
118	Linde Air Prod.	30	1943	1949	1979	W males	W males	995	27,740	LIND87
CIRCULATORY SYSTEM - Ischemic heart disease										
119	Linde Air Prod.	30	1943	1949	1979	W males	W males	995	27,740	LIND87
CIRCULATORY SYSTEM - Cerebrovascular disease										
110	Oak Ridge K25		1945	1984	1989	W males	Hourly pay category			ORK96
RESPIRATORY SYSTEM – All										
152	Linde Air Prod.	30	1943	1949	1979	W males	W males	995	27,740	LIND87
126	Oak Ridge K25		1945	1984	1989	W males	Hourly pay category			ORK96
119	Oak Ridge K25		1945	1984	1989	W males	W males	35,712		ORK96
112	Oak Ridge		1954	1985	1984	W males	W males			ORC97
RESPIRATORY SYSTEM – Pneumonia										
217	Linde Air Prod.	30	1943	1949	1979	W males	W males	995	27,740	LIND87
122	Oak Ridge K25		1945	1984	1989	W males	Hourly pay category			ORK96
117	Oak Ridge K25		1945	1984	1989	W males	W males	35,712		ORK96
RESPIRATORY SYSTEM – Emphysema										
120	Oak Ridge K25		1945	1984	1989	W males	Hourly pay category			ORK96
DIGESTIVE SYSTEM – Ulcers										
404	Oak Ridge K25		1943	1985	1989	W males	Welders at K25	683		ORC98
MUSCULOSKELETAL SYSTEM & CONNECTIVE TISSUE										
233	Hanford		1944	1978	1981	All females	Monitored-external			HAN89
206	Hanford		1944	1978	1986	All females	Monitored-external	8,895		HAN93a
138	Hanford		1944	1978	1986	All workers	All workers	44,154		HAN93a
SYMPTOMS & ILL-DEFINED CONDITIONS										
227	Los Alamos Zia		1946	1978	1984	W males	Monitored-external & Pu	4,942		LANL92
262	Oak Ridge		1943	1985	1989	W males	Welders	1,211		ORC98
593	Oak Ridge K25		1948	1953	1977	W males	Barrier workers (nickel)	814		ORK84
325	Oak Ridge K25		1948	1953	1977	W males	Comparison workers (no nickel)	7,552		ORK84
319	Oak Ridge K25		1945	1984	1989	W males	Hourly pay category			ORK96
301	Oak Ridge K25		1945	1984	1989	W males	W males	35,712		ORK96
249	Oak Ridge K25		1945	1984	1989	NW females	NW females			ORK96
227	Oak Ridge K25		1945	1984	1989	W females	W females			ORK96
289	Oak Ridge X10		1943	1972	1984	W males	Monitored- internal	3,763		ORX91
234	Oak Ridge X10		1943	1972	1984	W males	W males	8,318		ORX91
402	Oak Ridge Y12	2	1943	1945	1973	W males	Chemical workers (chronic low phosgene)	699	18,825	ORY80
323	Oak Ridge Y12	2	1943	1945	1973	W males	Comparison workers (no phosgene)	9,352	240,494	ORY80
330	Oak Ridge Y12	2	1943	1945	1978	W males	Comparison workers (no phosgene)	9,280	266,027	ORY85
325	Oak Ridge Y12	2	1943	1945	1978	W males	Chemical workers (chronic low	694	21,181	ORY85

							phosgene)			
293	Oak Ridge Y12		1947	1974	1990	W males	W males	6,591		ORY96
271	Oak Ridge Y12		1947	1974	1990	All workers	All workers	8,116		ORY96
ACCIDENTS, POISONINGS & VIOLENCE – All										
138	Hanford		1944	1978	1981	All females	Not monitored-external			HAN89
ACCIDENTS, POISONING & VIOLENCE – External										
119	Los Alamos Zia		1946	1978	1984	W males	Monitored-external & Pu	4,942		LANL92
105	Oak Ridge		1954	1985	1984	W males	W males			ORC97
116	Oak Ridge K25		1945	1984	1989	W males	Hourly pay category			ORK96
111	Oak Ridge K25		1945	1984	1989	W males	W males	35,712		ORK96
118	Oak Ridge Y12	2	1943	1945	1973	W males	Comparison workers (no phosgene)	9,352	240,494	ORY80
123	Oak Ridge Y12	2	1943	1945	1978	W males	Comparison workers (no phosgene)	9,280	266,027	ORY85
ACCIDENTS, POISONING & VIOLENCE - All accidents										
133	Los Alamos Zia	.	1946	1978	1984	W males	Monitored-external & Pu	4,942		LANL92
117	Oak Ridge K25	.	1945	1984	1989	W males	Hourly pay category			ORK96
112	Oak Ridge K25	.	1945	1984	1989	W males	W males	35,712		ORK96
ACCIDENTS, POISONING & VIOLENCE - Motor vehicle acidents										
170	Los Alamos Zia	.	1946	1978	1984	W males	Monitored-external & Pu	4,942		LANL97
123	Oak Ridge K25	.	1945	1984	1989	W males	Hourly pay category			ORK96
118	Oak Ridge K25	.	1945	1984	1989	W males	W males	35,712		ORK96

Table 3

All Statistically Significant Standardized Mortality Ratios (SMR) for Each Cause of Death Among DOE Contractor Employees

Standardized Mortality Ratio (SMR)*	Site	Minimum days worked	Employment period begins (Year)	Employment period ends (Year)	Deaths included through (Year)	Race & sex	Subgroup (exposure)	Number of employees	Person-years	Year of publication or report
ALL CAUSES OF DEATH COMBINED										
118	Linde Air Products	30	1943	1949	1979	W males	None	995	27,740	1987
106	Oak Ridge K25		1945	1984	1989	W males	Hourly pay category			1996
95	Oak Ridge Y12	2	1943	1945	1973	W males	Comparison workers (no phosgene)	9,352	240,494	1980
93	Mound		1944	1972	1983	W males	None	4,402	104,326	1991
92	Mound		1944	1972	1983	W males	Monitored-internal (Polonium)	2,181	56,256	1991
91	Oak Ridge Y12		1947	1974	1990	W males	None	6,591		1996
89	Oak Ridge		1954	1985	1984	W females	None			1997
89	Oak Ridge Y12	120	1953	1963	1978	W males	Nonmercury workers 4+ months	3,260		1984
88	Oak Ridge Y12		1947	1974	1990	All workers	None	8,116		1996
86	All DOE sites		1943	1978	1984	W males	DOE contractor	1,412	35,000	1996
86	Oak Ridge Y12	120	1953	1963	1978	W males	Mercury workers 4+ months	2,133		1984
85	Savannah River	90	1952	1986	1986	W males	Hourly pay category	7,299		1995
83	Oak Ridge	1	1948	1953	1972	W males	Comparison workers (no nickel)	1,600	34,701	1979
80	Oak Ridge Y12	120	1953	1963	1978	W males	Mercury workers 1+ years	1,741		1984
79	Mound		1947	1979	1979	W males	Monitored-external	4,182		1991
77	Los Alamos Zia		1946	1978	1984	W males	Monitored-external & Pu	4,942		1992
77	Oak Ridge Y12	120	1953	1963	1978	W males	Mercury workers (>0.3 mg Hg/L)	858		1984
76	Oak Ridge		1954	1985	1984	NW females	None			1997
75	Oak Ridge K25	1	1948	1953	1972	W males	Barrier workers (nickel)	814	17,232	1979
75	Oak Ridge K25		1945	1984	1989	W males	Monthly pay category			1996
74	Oak Ridge X10		1943	1972	1984	W males	None	8,318		1991
74	Rocky Flats		1952	1979	1977	W males	Monitored-external (<=100 mrem)	1,884		1983
73	Oak Ridge X10		1943	1972	1977	W males	None	8,375		1985
73	Portsmouth	1	1954	1991	1991	All workers	Monitored-internal (uranium)	6,827	150,000	1999
72	Pantex		1951	1978	1978	W males	None	3,564		1985
72	Portsmouth	1	1954	1991	1991	All worker	None	8,877	200,000	1999
72	Rocketdyne	1	1950	1993	1993	W males	Monitored-internal			1997
72	Savannah River	90	1952	1975	1980	W males	Hourly pay category	6,687		1988
71	Los Alamos		1943	1977	1990	W males	Hired before 1946	2,030	73,276	1994
71	Rocky Flats	730	1951	1977	1977	W males	Monitored-internal (2+ nCi Pu)			1983
69	Portsmouth	7	1954	1982	1982	W males	Potential U exposure	4,876	87,896	1987
68	Oak Ridge Y12	120	1953	1963	1978	W males	Mercury workers 4+ months	270		1984
68	Portsmouth	7	1954	1982	1982	W males	None	5,773	107,698	1987
68	Portsmouth	7	1954	1982	1982	W males	Greatest Potential U exposure	3,545	65,027	1987

68	Rocketdyne	1	1950	1993	1993	W males	Monitored-external	4,563	118,749	1997
68	Savannah River	90	1952	1975	1980	W males	Salaried pay category	2,745		1988
67	Oak Ridge Y12		1947	1974	1990	NW males	None	449		1996
65	Rocky Flats	730	1951	1977	1977	W males	Monitored-external (1+ rem)			1983
64	Rocky Flats	730	1951	1977	1977	W males	Employed 2+ years			1983
63	Los Alamos		1943	1977	1990	W males	None	5,727	456,637	1994
63	Oak Ridge X10		1943	1972	1984	W males	Monitored- internal	3,763		1991
63	Oak Ridge Y12		1947	1974	1990	All females	None	1,073		1996
62	Rocky Flats		1952	1979	1977	W males	Monitored-internal (<1 microCi/day)	4,982		1983
62	Rocky Flats	730	1952	1979	1979	W males	Employed 2+ years	5,413		1987
60	Savannah River	90	1952	1986	1986	W males	Salaried pay category	2,561		1995
56	Los Alamos		1944	1974	1980	W males	Monitored-internal (>10 nCi Pu)	224	6,930	1985
54	Los Alamos		1944	1974	1976	W males	Monitored-internal (>10 nCi Pu)	224		1978
49	Rocky Flats		1952	1979	1977	W males	Monitored-external (100+ mrem)	5,228		1983
36	Pantex		1951	1978	1978	W males	Monitored-external (1+ rem)	252		1985
All cancers combined										
89	Oak Ridge Y12	2	1943	1945	1978	W males	Comparison workers (no phosgene)	9,280	266,027	1985
86	Oak Ridge		1954	1985	1984	W females	None			1997
86	Savannah River	90	1952	1986	1986	W males	Hourly pay category	7,299		1995
85	Oak Ridge Y12	2	1943	1945	1973	W males	Comparison workers (no phosgene)	9,352	240,494	1980
82	Oak Ridge X10		1943	1972	1984	W males	Monitored- internal	3,763		1991
82	Portsmouth	1	1954	1991	1991	All workers	None	8,877	200,000	1999
79	Oak Ridge X10		1943	1972	1984	W males	None	8,318		1991
79	Rocketdyne	1	1950	1993	1993	W males	Monitored-external	4,563	118,749	1997
78	Oak Ridge		1954	1985	1984	NW females	None			1997
78	Oak Ridge X10		1943	1972	1977	W males	None	8,375		1985
76	Rocky Flats		1952	1979	1977	W males	Monitored-internal (<1 microCi/day)	4,982		1983
75	Los Alamos Zia		1946	1978	1984	W males	Monitored-external & Pu	4,942		1992
75	None		1943	1971	1977	W males	None	2,002	43,252	1983
75	Rocky Flats	730	1951	1977	1977	W males	Employed 2+ years			1983
71	Rocky Flats	730	1952	1979	1979	W males	Employed 2+ years	5,413		1987
71	Savannah River	90	1952	1986	1986	W males	Salaried pay category	2,561		1995
70	Oak Ridge K25		1945	1984	1989	W males	Monthly pay category			1996
69	Los Alamos		1943	1977	1990	W males	Hired before 1946	2,030	73,276	1994
64	Los Alamos		1943	1977	1990	W males	None	15,727	456,637	1994
60	Pantex		1951	1978	1978	W males	None	3,564		1985
All cancers (excluding leukemia)										
121	Fernald	1	1951	1981	1989	W males	Hourly pay category	4,014	121,038	1996
Infections & parasitic diseases										
40	Oak Ridge Y12		1947	1974	1990	W males	None	6,591		1996
38	Oak Ridge Y12		1947	1974	1990	All workers	None	8,116		1996
37	Oak Ridge K25		1945	1984	1989	W males	Monthly pay category			1996
30	Savannah River	90	1952	1975	1980	W males	Hourly pay category	6,687		1988
Cancer-buccal cavity & pharynx										
79	Oak Ridge		1954	1985	1984	W males	None			1997
55	Los Alamos		1943	1977	1990	W males	None	15,727	456,637	1994
23	Oak Ridge K25		1948	1953	1977	W males	Comparison workers (no nickel)	7,552		1984
23	Oak Ridge Y12		1947	1974	1990	W males	None	6,591		1996
21	Oak Ridge Y12		1947	1974	1990	All workers	None	8,116		1996

13	Oak Ridge K25		1945	1984	1989	W males	Monthly pay category			1996
Cancer-digestive organs & peritoneum										
81	Oak Ridge K25		1945	1984	1989	W males	None	35,712		1996
80	Oak Ridge		1943	1947	1979	W males	None	28,008		1990
79	Oak Ridge		1954	1985	1984	W males	None			1997
74	Los Alamos		1943	1977	1990	W males	Hired before 1946	2,030	73,276	1994
74	Los Alamos		1943	1977	1990	W males	None	15,727	456,637	1994
71	Oak Ridge		1954	1985	1984	W females	None			1997
66	Oak Ridge Y12	2	1943	1945	1978	W males	Comparison workers (no phosgene)	9,280	266,027	1985
65	Oak Ridge K25		1945	1984	1989	W males	Monthly pay category			1996
64	Oak Ridge		1954	1985	1984	NW females	None			1997
63	Oak Ridge Y12	2	1943	1945	1973	W males	Comparison workers (no phosgene)	9,352	240,494	1980
62	Savannah River	90	1952	1986	1986	W males	Salaried pay category	2,561		1995
58	Savannah River	90	1952	1975	1980	W males	Salaried pay category	2,745		1988
Cancer-esophagus										
82	Oak Ridge		1954	1985	1984	W males	None			1997
41	Oak Ridge Y12		1947	1974	1990	All workers	None	8,116		1996
Cancer-stomach										
281	Fernald	1	1951	1981	1989	W males	Salaried pay category	4,014	121,038	1996
165	Los Alamos Zia		1946	1978	1984	W males	Monitored-external & Pu	4,942		1992
73	Oak Ridge		1954	1985	1984	W males	None			1997
70	Los Alamos		1943	1977	1990	W males	None	15,727	456,637	1994
Cancer-colon										
81	Oak Ridge		1954	1985	1984	W males	None			1997
78	Oak Ridge		1943	1947	1979	W males	None	28,008		1990
73	Los Alamos		1943	1977	1990	W males	None	15,727	456,637	1994
71	Oak Ridge		1954	1985	1984	W females	None			1997
57	Los Alamos		1943	1977	1990	W males	Hired before 1946	2,030	73,276	1994
53	Los Alamos Zia		1946	1978	1984	W males	Monitored-external & Pu	4,942		1992
Cancer-rectum										
58	Los Alamos		1943	1977	1990	W males	None	15,727	456,637	1994
55	Oak Ridge		1954	1985	1984	W males	None			1997
53	Oak Ridge		1943	1947	1979	W males	None	28,008		1990
42	Oak Ridge X10		1943	1972	1984	W males	None	8,318		1991
39	Oak Ridge		1954	1985	1984	W females	None			1997
33	Los Alamos Zia		1946	1978	1984	W males	Monitored-external & Pu	4,942		1992
Cancer-Liver & gallbladder										
78	Oak Ridge		1954	1985	1984	W males	None			1997
53	Oak Ridge		1954	1985	1984	W females	None			1997
Cancer-pancreas										
169	Hanford**		1944	1978	1981	All males	Not monitored-external			1989
157	Hanford**		1944	1978	1986	All males	Not monitored-external	3,400		1993
14	Oak Ridge		1954	1985	1984	NW females	None			1997
Cancer-respiratory system										
125	Fernald	1	1951	1981	1989	W males	Hourly pay category	4,014	121,038	1996
125	Oak Ridge		1943	1947	1979	W males	None	28,008		1990
123	Oak Ridge K25		1945	1984	1989	W males	Hourly pay category			1996
119	Oak Ridge Y12		1947	1974	1990	W males	None	6,591		1996
117	Oak Ridge K25		1945	1984	1989	W males	None	35,712		1996

116	Oak Ridge		1954	1985	1984	W males	None			1997
73	Oak Ridge K25		1945	1984	1989	W males	Monthly pay category			1996
66	Savannah River	90	1952	1975	1980	W males	Salaried pay category	2,745		1988
59	Savannah River	90	1952	1986	1986	W males	Salaried pay category	2,561		1995
56	Los Alamos		1943	1977	1990	W males	Hired before 1946	2,030	73,276	1994
Cancer-larynx										
447	Linde Air Products	30	1943	1949	1979	W males	None	995	27,740	1987
32	Los Alamos		1943	1977	1990	W males	None	15,727	456,637	1994
Cancer-trachea, bronchus and lung										
138	Oak Ridge		1943	1985	1989	W males	Welders	1,211		1998
136	Oak Ridge Y12		1947	1974	1979	W males	None	6,781		1985
134	Oak Ridge Y12	120	1953	1963	1978	W males	Nonmercury workers 4+ months	3,260		1984
127	Oak Ridge		1943	1947	1979	W males	None	28,008		1990
125	Fernald	1	1951	1981	1989	W males	Hourly pay category	4,014	121,038	1996
124	Oak Ridge K25		1945	1984	1989	W males	Hourly pay category			1996
120	Oak Ridge Y12		1947	1974	1990	W males	None	6,591		1996
119	Oak Ridge K25		1945	1984	1989	W males	None	35,712		1996
118	Oak Ridge		1954	1985	1984	W males	None			1997
118	Oak Ridge Y12	2	1943	1945	1978	W males	Comparison workers (no phosgene)	9,280	266,027	1985
78	Portsmouth	1	1954	1991	1991	All workers	Monitored-internal (uranium)	6,827	150,000	1999
77	Oak Ridge K25		1945	1984	1989	W males	Monthly pay category			1996
75	Oak Ridge X10		1943	1972	1977	W males	None	8,375		1985
75	Rocketdyne	1	1950	1993	1993	W males	Monitored-external	4,563	118,749	1997
72	Oak Ridge X10		1943	1972	1984	W males	Monitored- internal	3,763		1991
65	Oak Ridge X10		1943	1972	1984	W males	None	8,318		1991
64	Rocky Flats	730	1952	1979	1979	W males	Employed 2+ years	5,413		1987
62	Fernald	1	1951	1981	1989	W males	Salaried pay category	4,014	121,038	1996
62	Rocky Flats	730	1951	1977	1977	W males	Employed 2+ years			1983
61	Los Alamos Zia		1946	1978	1984	W males	Monitored-external & Pu	4,942		1992
55	Los Alamos		1943	1977	1990	W males	Hired before 1946	2,030	73,276	1994
49	Pantex		1951	1978	1978	W males	None	3,564		1985
45	Los Alamos		1943	1977	1990	W males	None	15,727	456,637	1994
Cancer-bone										
191	Oak Ridge K25		1945	1984	1989	W males	Hourly pay category			1996
182	Oak Ridge K25		1945	1984	1989	W males	None	35,712		1996
1	Oak Ridge Y12		1947	1974	1990	NW males	None	449		1996
Cancer-breast (female)										
86	Oak Ridge		1954	1985	1984	W females	None			1997
55	Oak Ridge		1954	1985	1984	NW females	None			1997
Cancer-genitals (female)										
87	Oak Ridge		1954	1985	1984	W females	None			1997
70	Oak Ridge		1954	1985	1984	NW females	None			1997
Cancer-ovary										
79	Oak Ridge		1954	1985	1984	W females	None			1997
38	Oak Ridge		1954	1985	1984	NW females	None			1997
Cancer-prostate										
195	Oak Ridge		1943	1985	1989	W males	X10/Y12/TEC welders	1,211		1998
67	Los Alamos		1943	1977	1990	W males	None	15,727	456,637	1994
Cancer-bladder										

76	Oak Ridge		1954	1985	1984	W males	None			1997
60	Los Alamos		1943	1977	1990	W males	None	15,727	456,637	1994
Cancer-leukemia										
223	Oak Ridge X10	30	1944	1978	1981	W males	Monitored-internal	3,763		1989
163	Oak Ridge X10	30	1944	1978	1986	W males	Monitored-external	3,400	1991	
20	Oak Ridge K25	30	1945	1984	1989	W males	Monthly pay category	3,287		1989
Benign & unspecified tumors										
600	Rocky Flats	730	1951	1977	1977	W males	Monitored-external (1+ rem)			1983
405	Rocky Flats	730	1951	1977	1977	W males	Employed 2+ years			1983
376	Rocky Flats	730	1952	1979	1979	W males	Employed 2+ years	5,413		1987
98	Oak Ridge Y12		1947	1974	1990	NW males	None	449		1996
Endocrine, metabolic & nutritional										
62	Oak Ridge Y12		1947	1974	1990	W males	None	6,591		1996
56	Oak Ridge Y12		1947	1974	1990	All workers	None	8,116		1996
Diabetes										
55	Mallinckrodt		1942	1966	1993	W males	Monitored-external	2,514	87,757	1998
24	Savannah River	90	1952	1975	1980	W males	Hourly pay category	6,687		1988
Blood & blood-forming organs										
52	Oak Ridge		1954	1985	1984	W males	None			1997
Mental disorders										
164	Oak Ridge K25		1945	1984	1989	W males	Hourly pay category			1996
159	Oak Ridge K25		1945	1984	1989	W males	None	35,712		1996
141	Oak Ridge Y12	2	1943	1945	1973	W males	Comparison workers (no phosgene)	9,352	240,494	1980
Nervous system & sense organs										
70	Oak Ridge		1954	1985	1984	W males	None			1997
55	Oak Ridge Y12		1947	1974	1990	All workers	None	8,116		1996
44	Portsmouth	7	1954	1982	1982	W males	Potential U exposure	4,876	87,896	1987
40	Portsmouth	7	1954	1982	1982	W males	None	5,773	107,698	1987
37	Oak Ridge		1954	1985	1984	W females	None			1997
26	Portsmouth	7	1954	1982	1982	W males	Greatest Potential U exposure	3,545	65,027	1987
Circulatory system										
118	Linde Air Products	30	1943	1949	1979	W males	None	995	27,740	1987
95	Oak Ridge		1954	1985	1984	W males	None			1997
90	Mound		1944	1972	1983	W males	None	4,402	104,326	1991
90	Oak Ridge Y12	2	1943	1945	1978	W males	Comparison workers (no phosgene)	9,280	266,027	1985
89	Savannah River	90	1952	1986	1986	W males	Hourly pay category	7,299		1995
88	Fernald	1	1951	1981	1989	W males	Hourly pay category	4,014	121,038	1996
88	Mallinckrodt		1942	1966	1993	W males	Monitored-external	2,514	87,757	1998
88	Oak Ridge		1954	1985	1984	NW males	None			1997
87	Oak Ridge Y12		1947	1974	1990	W males	None	6,591		1996
86	Savannah River	90	1952	1975	1980	W males	Hourly pay category	6,687		1988
84	Oak Ridge		1954	1985	1984	W females	None			1997
83	Oak Ridge Y12		1947	1974	1990	All workers	None	8,116		1996
82	Mound		1947	1979	1979	W males	Monitored-external	4,182		1991
80	All DOE sites		1943	1978	1984	W males	DOE contractor	1,412	35,000	1996
78	Oak Ridge K25		1945	1984	1989	W males	Monthly pay category			1996
76	Pantex		1951	1978	1978	W males	None	3,564		1985
72	Portsmouth	7	1954	1982	1982	W males	None	5,773	107,698	1987
70	Oak Ridge		1954	1985	1984	NW females	None			1997

70	Portsmouth	7	1954	1982	1982	W males	Potential U exposure	4,876	87,896	1987
70	Savannah River	90	1952	1975	1980	W males	Salaried pay category	2,745		1988
68	Portsmouth	7	1954	1982	1982	W males	Greatest Potential U exposure	3,545	65,027	1987
68	Rocketdyne	1	1950	1993	1993	W males	Monitored-internal			1997
65	Los Alamos		1943	1977	1990	W males	Hired before 1946	2,030	73,276	1994
63	Rocketdyne	1	1950	1993	1993	W males	Monitored-external	4,563	118,749	1997
62	Fernald	1	1951	1981	1989	W males	Salaried pay category	4,014	121,038	1996
62	Savannah River	90	1952	1986	1986	W males	Salaried pay category	2,561		1995
57	Los Alamos		1943	1977	1990	W males	None	15,727	456,637	1994
55	Oak Ridge Y12		1947	1974	1990	NW males	None	449		1996
45	Los Alamos		1944	1974	1980	W males	Monitored-internal (>10 nCi Pu)	224	6,930	1985
40	Oak Ridge Y12		1947	1974	1990	All females	None	1,073		1996
38	Los Alamos		1944	1974	1976	W males	Monitored-internal (>10 nCi Pu)	224		1978
							Ischemic heart disease			
119	Linde Air Products	30	1943	1949	1979	W males	None	995	27,740	1987
77	Savannah River	90	1952	1975	1980	W males	Salaried pay category	2,745		1988
75	Oak Ridge X10		1943	1972	1977	W males	None	8,375		1985
66	Savannah River	90	1952	1986	1986	W males	Salaried pay category	2,561		1995
61	Rocketdyne	1	1950	1993	1993	W males	Monitored-internal			1997
58	Rocketdyne	1	1950	1993	1993	W males	Monitored-external	4,563	118,749	1997
32	Rocketdyne	1	1950	1993	1993	All females	Monitored-external			1997
							Cerebrovascular disease			
110	Oak Ridge K25		1945	1984	1989	W males	Hourly pay category			1996
61	Savannah River	90	1952	1986	1986	W males	Salaried pay category	2,561		1995
57	Rocketdyne	1	1950	1993	1993	W males	Monitored-external	4,563	118,749	1997
							Respiratory system			
152	Linde Air Products	30	1943	1949	1979	W males	None	995	27,740	1987
126	Oak Ridge K25		1945	1984	1989	W males	Hourly pay category			1996
119	Oak Ridge K25		1945	1984	1989	W males	None	35,712		1996
112	Oak Ridge		1954	1985	1984	W males	None			1997
74	Oak Ridge		1943	1973	1973	W males	Welders	1,059	23,674	1981
69	Los Alamos		1943	1977	1990	W males	None	15,727	456,637	1994
63	Oak Ridge K25		1945	1984	1989	W males	Monthly pay category			1996
61	Oak Ridge X10		1943	1972	1984	W males	None	8,318		1991
57	Oak Ridge		1954	1985	1984	NW females	None			1997
56	Rocketdyne	1	1950	1993	1993	W males	Monitored-external	4,563	118,749	1997
55	Savannah River	90	1952	1986	1986	W males	Hourly pay category	7,299		1995
46	Portsmouth	7	1954	1982	1982	W males	Potential U exposure	4,876	87,896	1987
42	Fernald	1	1951	1981	1989	W males	Salaried pay category	4,014	121,038	1996
42	Portsmouth	7	1954	1982	1982	W males	None	5,773	107,698	1987
42	Savannah River	90	1952	1986	1986	W males	Salaried pay category	2,561		1995
41	Savannah River	90	1952	1975	1980	W males	Hourly pay category	6,687		1988
40	Portsmouth	7	1954	1982	1982	W males	Greatest Potential U exposure	3,545	65,027	1987
36	Oak Ridge X10		1943	1972	1977	W males	None	8,375		1985
30	Savannah River	90	1952	1975	1980	W males	Salaried pay category	2,745		1988
16	Oak Ridge Y12		1947	1974	1990	All females	None	1,073		1996
							Pneumonia			
217	Linde Air Products	30	1943	1949	1979	W males	None	995	27,740	1987
122	Oak Ridge K25		1945	1984	1989	W males	Hourly pay category			1996

117	Oak Ridge K25		1945	1984	1989	W males	None	35,712		1996
33	Savannah River	90	1952	1975	1980	W males	Hourly pay category	6,687		1988
12	Savannah River	90	1952	1975	1980	W males	Salaried pay category	2,745		1988
Emphysema										
120	Oak Ridge K25		1945	1984	1989	W males	Hourly pay category			1996
20	Oak Ridge K25		1945	1984	1989	W males	Monthly pay category			1996
Digestive system										
85	Oak Ridge		1954	1985	1984	W females	None			1997
84	Oak Ridge K25		1945	1984	1989	W males	Hourly pay category			1996
81	Oak Ridge K25		1945	1984	1989	W males	None	35,712		1996
80	Oak Ridge		1954	1985	1984	W males	None			1997
80	Oak Ridge Y12	2	1943	1945	1978	W males	Comparison workers (no phosgene)	9,280	266,027	1985
76	Oak Ridge Y12	2	1943	1945	1973	W males	Comparison workers (no phosgene)	9,352	240,494	1980
73	Oak Ridge		1954	1985	1984	NW males	None			1997
63	Los Alamos		1943	1977	1990	W males	None	15,727	456,637	1994
62	Oak Ridge Y12		1947	1974	1990	W males	None	6,591		1996
60	Oak Ridge Y12		1947	1974	1990	All workers	None	8,116		1996
59	Oak Ridge K25		1945	1984	1989	W males	Monthly pay category			1996
57	Portsmouth	7	1954	1982	1982	W males	Potential U exposure	4,876	87,896	1987
57	Savannah River	90	1952	1986	1986	W males	Hourly pay category	7,299		1995
54	All DOE sites		1943	1978	1984	W males	DOE contractor	1,412	35,000	1996
54	Portsmouth	7	1954	1982	1982	W males	None	5,773	107,698	1987
54	Savannah River	90	1952	1975	1980	W males	Hourly pay category	6,687		1988
52	Oak Ridge		1954	1985	1984	NW females	None			1997
46	Pantex		1951	1978	1978	W males	None	3,564		1985
42	Rocketdyne	1	1950	1993	1993	W males	Monitored-external	4,563	118,749	1997
41	Rocketdyne	1	1950	1993	1993	W males	Monitored-internal			1997
40	Savannah River	90	1952	1986	1986	W males	Salaried pay category	2,561		1995
34	Savannah River	90	1952	1975	1980	W males	Salaried pay category	2,745		1988
Liver-cirrhosis										
60	Savannah River	90	1952	1986	1986	W males	Hourly pay category	7,299		1995
58	Savannah River	90	1952	1975	1980	W males	Hourly pay category	6,687		1988
45	Rocketdyne	1	1950	1993	1993	W males	Monitored-external	4,563	118,749	1997
35	Savannah River	90	1952	1986	1986	W males	Salaried pay category	2,561		1995
31	Savannah River	90	1952	1975	1980	W males	Salaried pay category	2,745		1988
Genitourinary system										
83	Oak Ridge		1954	1985	1984	W males	None			1997
64	Oak Ridge		1954	1985	1984	W females	None			1997
63	Oak Ridge		1954	1985	1984	NW females	None			1997
59	Oak Ridge Y12		1947	1974	1990	All workers	None	8,116		1996
55	Oak Ridge Y12		1947	1974	1990	W males	None	6,591		1996
54	Oak Ridge K25		1945	1984	1989	W females	None			1996
39	Savannah River	90	1952	1975	1980	W males	Hourly pay category	6,687		1988
Nephritis & nephrosis										
32	Fernald	1	1951	1981	1989	W males	Hourly pay category	4,014	121,038	1996
Musculoskeletal system & connective tissue										
233	Hanford**		1944	1978	1981	All females	Monitored-external			1989
206	Hanford**		1944	1978	1986	All females	Monitored-external	8,895		1993
138	Hanford**		1944	1978	1986	All workers	None	44,154		1993

Symptoms & ill-defined conditions										
593	Oak Ridge K25		1948	1953	1977	W males	Barrier workers (nickel)	814		1984
402	Oak Ridge Y12	2	1943	1945	1973	W males	Chemical workers (chronic low phosgene)	699	18,825	1980
330	Oak Ridge Y12	2	1943	1945	1978	W males	Comparison workers (no phosgene)	9,280	266,027	1985
325	Oak Ridge K25		1948	1953	1977	W males	Comparison workers (no nickel)	7,552		1984
325	Oak Ridge Y12	2	1943	1945	1978	W males	Chemical workers (chronic low phosgene)	694	21,181	1985
323	Oak Ridge Y12	2	1943	1945	1973	W males	Comparison workers (no phosgene)	9,352	240,494	1980
319	Oak Ridge K25		1945	1984	1989	W males	Hourly pay category			1996
301	Oak Ridge K25		1945	1984	1989	W males	None	35,712		1996
293	Oak Ridge Y12		1947	1974	1990	W males	None	6,591		1996
289	Oak Ridge X10		1943	1972	1984	W males	Monitored- internal	3,763		1991
271	Oak RidgeY12		1947	1974	1990	All workers	None	8,116		1996
262	Oak Ridge		1943	1985	1989	W males	Welders	1,211		1998
249	Oak Ridge K25		1945	1984	1989	NW females	None			1996
234	Oak Ridge X10		1943	1972	1984	W males	None	8,318		1991
227	Los Alamos Zia		1946	1978	1984	W males	Monitored-external & Pu	4,942		1992
227	Oak Ridge K25		1945	1984	1989	W females	None			1996
Accidents, poisonings & violence										
138	Hanford**		1944	1978	1981	All females	Not monitored-external			1989
36	Portsmouth	7	1954	1982	1982	W males	None	5,773	107,698	1987
Accidents, poisoning & violence-External										
123	Oak Ridge Y12	2	1943	1945	1978	W males	Comparison workers (no phosgene)	9,280	266,027	1985
119	Los Alamos Zia		1946	1978	1984	W males	Monitored-external & Pu	4,942		1992
118	Oak Ridge Y12	2	1943	1945	1973	W males	Comparison workers (no phosgene)	9,352	240,494	1980
116	Oak Ridge K25		1945	1984	1989	W males	Hourly pay category			1996
111	Oak Ridge K25		1945	1984	1989	W males	None	35,712		1996
105	Oak Ridge		1954	1985	1984	W males	None			1997
86	Oak Ridge Y12		1947	1974	1990	All workers	None	8,116		1996
82	Mound		1944	1972	1983	W males	None	4,402	104,326	1991
77	Los Alamos		1943	1977	1990	W males	None	15,727	456,637	1994
75	Oak Ridge X10		1943	1972	1984	W males	None	8,318		1991
72	Los Alamos		1943	1977	1990	W males	Hired before 1946	2,030	73,276	1994
72	Oak Ridge K25	.	1945	1984	1989	W males	Monthly pay category			1996
66	Rocketdyne	1	1950	1993	1993	W males	Monitored-external	4,563	118,749	1997
63	Mound	.	1947	1979	1979	W males	Monitored-external	4,182		1991
62	Rocketdyne	1	1950	1993	1993	W males	Monitored-internal			1997
57	Fernald	1	1951	1981	1989	W males	Salaried pay category	4,014	121,038	1996
53	Savannah River	90	1952	1975	1980	W males	Salaried pay category	2,745		1988
51	Oak Ridge X10	.	1943	1972	1984	W males	Monitored- internal	3,763		1991
45	Savannah River	90	1952	1986	1986	W males	Salaried pay category	2,561		1995
Unintentional injuries										
68	Los Alamos	.	1943	1977	1990	W males	None	15,727	456,637	1994
59	Los Alamos	.	1943	1977	1990	W males	Hired before 1946	2,030	73,276	1994
All accidents										
133	Los Alamos Zia	.	1946	1978	1984	W males	Monitored-external & Pu	4,942		1992
117	Oak Ridge K25	.	1945	1984	1989	W males	Hourly pay category			1996
112	Oak Ridge K25	.	1945	1984	1989	W males	None	35,712		1996
73	Oak Ridge K25	.	1945	1984	1989	W males	Monthly pay category			1996

60	Savannah River	90	1952	1975	1980	W males	Salaried pay category	2,745		1988
54	Portsmouth	7	1954	1982	1982	W males	Greatest Potential U exposure	3,545	65,027	1987
53	Portsmouth	7	1954	1982	1982	W males	Potential U exposure	4,876	87,896	1987
51	Savannah River	90	1952	1986	1986	W males	Salaried pay category	2,561		1995
Motor vehicle acidents										
170	Los Alamos Zia	.	1946	1978	1984	W males	Monitored-external & Pu	4,942		1992
123	Oak Ridge K25	.	1945	1984	1989	W males	Hourly pay category			1996
118	Oak Ridge K25	.	1945	1984	1989	W males	None	35,712		1996
60	Oak Ridge X10	.	1943	1972	1977	W males	None	8,375		1985

APPENDIX 5

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APPENDIX 6

FREQUENTLY CITED DOE CHEMICAL & PHYSICAL CONTAMINANTS

METALS
- Arsenic
- Beryllium
- Cadmium
- Chromium
- Copper
- Lead
- Mercury
- Nickel (welding)
- Zinc

RADIONUCLIDES
- Cesium
- Iodine
- Plutonium
- Polonium
- Strontium
- Tritium
- Uranium

GASES/PARTICLES
- Asbestos
- Diesel emissions
- Fiberglass
- Freon
- Metal machining fluids
- Phosgene
- Radon
- Silica

CHLORINATED HYDROCARBONS
- TCE
- 1,1,1-trichloroethane
- 1,2-dichloroethylene
- Tetrachloroethylene
- 1,1-dichloroethane
- Chloroform
- PCBs
- Methylene chloride

FUEL HYDROCARBONS
- Benzene
- Ethylbenzene
- Toluene
- Xylenes

KETONES
- Acetone
- Methyl ethyl ketone

PHTHALATES
- Bis-2-ethylexylphthalate

OTHER HAZARDS
- Acids
- Epoxy resins
- Fluorine compounds
- Formaldehyde
- Heat
- Hydrazine
- Mixed chemicals
- Noise
- Volatile organic compounds

Source: Chemical Contaminants on DOE Lands and Selection of Contaminants Mixtures for Subsurface Science Research. DOE/ER-0547T. April 1992.

APPENDIX 7
DOE Facilities and Sites by Role in the Nuclear Weapons Production

	U refining and metallurgy	U enrichment & isotope separation	U Fuel rods & targets	Production reactors	Chemical separations	Nuclear components	Non nuclear components	Weapons assembly & modification	Research & Development	Testing		Reference most recent morbidity/mortality study
Amchitka Island Test Site (AK)										•		-
*Argonne National Laboratory**									•			-
Atlantic & Southern Pacific Test Sites										•		-
Fernald Feed Materials Production Center (OH)	•		•									FMPC96
Hanford Site (WA)			•	•	•	•			•			HAN93a
INEEL (ID)					•				•			-
Kansas City Plant (MO)							•					-
Lawrence Berkeley National Laboratory (CA)									•			-
Lawrence Livermore National Laboratory (CA)									•			LLNL85a
Linde Air Products (NY)	•											LIND87
Los Alamos National Laboratory (NM)						•			•			LANL94
Mallinckrodt Chemical Works (MO)	•											MCW98
Mound Facility (OH)						•	•					MND91a
Nevada Test Site										•		-
Oak Ridge K-25 GDP (TN)		•										ORK96
Oak Ridge X-10 (TN)								•				ORX91
Oak Ridge Y-12 (TN)	•	•	•			•						ORY97b
Paducah GDP (KY)		•										-
Pantex Plant (TX)						•	•					PTX85
Pinellas Plant (FL)						•	•					-
Portsmouth GDP (OH)		•										PTS87
Project Plowshare Test Sites (NV,NM,CO)										•		-
Rocky Flats Plant (CO)						•						RFP83
Sandia National Laboratory (NM)									•			-
Savannah River Site (SC)		•	•	•	•				•			SRS94
Tatum Dome/Vela Uniform Test Sites (AK,MS,NV)										•		VELA98
Weldon Springs (MO)	•											-

*Italics indicates that no mortality study has been initiated. The Idaho National Engineering and Environmental Laboratory in currently under study. Naval Nuclear facilities, by executive order, are a separate and independent program.

APPENDIX 8

SUMMARY OF FINDINGS FROM SPECIAL RADIATION STUDIES

1) Los Alamos Plutonium Workers:

- Twenty-six white male workers, who did the original plutonium research and development work at the Los Alamos National Laboratory before 1946 and received large internal deposition, volunteered for this medical monitoring program.
- They have been medically evaluated every five years for possible health effects.
- The average dose each worker received over the 50-year period since 1945 was 1,250 mSv (125 rem).
- The initial exposures were large- some 5 to 360 times the current annual limit on intake.

Results:

- To date there have been 7 worker deaths in this group.
- Three have died from cancers (lung, prostate, osteosarcoma).
- The one bone cancer (osteosarcoma) which a rare condition is of interest since plutonium is known to deposit in the bone.

Reference: George L. Voelz, James N. P. Lawrence, and Emily R. Johnson. 1997. Fifty Years of Plutonium Exposure to the Manhattan Project Plutonium Workers: an Update. Health Physics 73(4):611-619.

2) Rocky Flats High RAD Workers Program:

In July 1992, a program was initiated that replaced a Rocky Flats Site Clinic program aimed at former employees with internal depositions of radionuclides. The surveillance program is aimed at any former worker with more than 200 mSv (20 rem) lifetime total effective dose equivalent (TEDE) exposure to both internal and external radiation. In addition to providing periodic medical surveillance, the program collects health histories of high dose workers and develops doses models of internal depositions.

To date 860 individuals have been examined. More than 400 are eligible to continue participation based on lifetime TEDEs greater than 200 mSv. A sentinel case of lung fibrosis among plutonium-exposed worker has been diagnosed. Of 251 former worker records that have been analyzed, 4.9% show chest X-ray changes consistent with asbestos exposure. A complete analysis of other health outcomes is pending.

3) **US Transuranium and Uranium Registries**:

Background

The United States Transuranium and Uranium Registries (USTUR) are a unique DOE-sponsored research program that studies how plutonium, uranium and other heavy radioactive metals (called actinides) distribute themselves within the human body and what biological effects those metals have on body organs. Organ samples are acquired post-mortem from volunteer donors who worked with the radioactive metals and who, at some time during their work history, had an established intake of those metals into their bodies.

- During the past 30 years, the USTUR has received autopsy samples from about 360 donors. Of these, 24 have been whole body donations, providing a unique opportunity for thorough investigation of the distribution of actinides in the human body. The analyses of bones of entire skeletons from whole body donations, has enabled the USTUR to determine the radiation dose to bone and its relationship to radiation-induced bone tumors, which are one of the prime concerns of radiation protection regulations governing intakes of the actinide elements.

- Approximately 5,000 organ samples have been collected and analyzed for isotopes of uranium, plutonium, thorium, and americium resulting in more than 15,000 analytical results for various organs of the body. These measurements have formed the basis for a large number of scientific reports, and 133 of those reports have been published in the peer-reviewed, scientific literature.

- The program continues to add to this unique set of data through the continued donation of tissues from exposed workers with confirmed intakes. At present, there are about 230 living workers or former workers who are registered in the program.

Results:

A number of observations regarding the health effects of plutonium, americium, and other elements in the body are possible based on USTUR data. Among them:

1. Table 1 summarizes the causes of death among 244 USTUR organ donors. The average age at death of USTUR registrants is 63 years (range between 25 and 91 years). The average age of USTUR registrants who are still living is 73 years (range between 30 and 93 years).

2. There were 28 cases of lung cancer among USTUR. There were also six cases of mesothelioma, a type of cancer associated with asbestos exposure A records review indicated asbestos handling in the work histories of all six of these cases.

3. There were seven brain cancers at Rocky Flats, a plutonium processing facility. Three of the workers had very low body burdens of plutonium at death (less than 1% of the regulatory limit, which was 40 nanocuries in the total body). The remaining four individuals had depositions far below that amount.

4. Of the 244 registrants for whom cause of death is known, there were two cases in which diseases found at death may be considered a result of intakes of plutonium or americium. One individual was a Hanford worker who received a very high exposure to americium from a chemical explosion of material that he was handling. Initial estimates were that he had 4 – 5 times the regulatory limit in his lungs, liver, and skeleton with four times that embedded in the skin of his face. This person had decreased numbers of certain blood cells that began after the incident and continued until his death eleven years later from heart disease. Another worker, who had been exposed to plutonium, died from bone

cancer (osteosarcoma). Bone cancer is rare in someone of his age (66 years at death) and it is one of the tumors associated with intakes of plutonium in experiments with animals.

5. The vast majority of USTUR organ sample donors had plutonium body burdens that were less than 5% of the regulatory limit at the time that they worked with plutonium. It would appear based on USTUR follow-up that, with exceptions mentioned above, they suffered no health effects from plutonium. However, this appears not be the case with Russian workers who have much larger plutonium exposures: on average, the Russian workers had approximately 250 times as much plutonium in their bodies as did the workers in the USTUR. While the studies of Russian workers are not yet complete, it appears that they did have larger than usual numbers of lung cancers, liver cancers, bone cancers, and cases of lung fibrosis. The average plutonium body burden of the Russian workers was approximately 60 nanocuries or about 1.5 times the U. S. regulatory limit.

Table 1. Causes of death among 244 workers who donated organ samples to the USTUR

Cause of Death	Number	Cause of Death	Number
Diseases of blood		Esophageal cancer	2
forming organs	1	Stomach cancer	4
Neurological diseases	7	Colon cancer	4
Arteriosclerotic heart		Rectal cancer	3
disease	80	Liver cancer	4
Other circulatory disease	2	Pancreatic cancer	3
Pulmonary embolism	4	Laryngeal cancer	2
Myocarditis	1	Lung cancer	28
Cardiomyopathy	9	Mesothelioma	6
Diffuse arteriosclerosis	1	Bone cancer	1
Cerebrovascular accidents	8	Melanoma	4
Vascular diseases	3	Prostate cancer	7
Pneumonia	5	Bladder cancer	2
Chronic obstructive		Kidney cancer	4
pulmonary disease	10	Brain cancer	7
Intestinal diseases	1	Lymphoma	2
Liver diseases	4	Multiple myeloma	1
Aspiration	1	Leukemia	3
Sepsis	2		
Accidents (auto)	7		
Suicides	7		

Reference: *Health Physics* 75:236-240, 1998

APPENDIX 9

SUMMARY OF FINDINGS FROM OTHER SURVEILLANCE PROGRAMS

1) The Epidemiologic Surveillance Program

Background

About 65,000 workers are covered under this program. Data from the most recent year where complete information is available, 1997, are presented. The SHEO's are identified from return-to-work clearances that indicate illness and injury diagnoses among workers who have been absent five or more consecutive workdays.

A sentinel health event for occupations (SHEOs) is a "disease, disability, or death which is occupationally related and whose occurrence may serve as a warning signal that materials substitution, engineering controls, personal protection, or medical care may be required." Sixty-four medical conditions associated with workplace exposures from studies of many different industries were identified as sentinel health events. Although SHEOs may indicate an occupational exposure, many may result from non-occupational exposures. Due to this uncertainty, SHEOs are assessed in two categories: 1) definite sentinel health events – diseases that are unlikely to occur in the absence of an occupational exposure, and 2) possible sentinel health events – conditions that may or may not be related to occupation.

Results:

There were 516 SHEO's (definite and possible) identified among workers at 8 DOE sites participating in the Epidemiologic Surveillance program in 1997.

Injuries (n= 311) account for the majority, 60.3% of the SHEOs, followed by 80 (15.5%) muscle and skeletal disorders, and 73 (14.1%) diagnoses related to the nervous system. Thirteen (2.5%) cancers and 7 (1.4%) respiratory diagnoses were identified as SHEOs. The breakdown by International Classification of Disease (ICD 9th revision) code for the latter three categories is provided in Table 1.

Table 1

Breakout of Selected Sentinel Health Events for Occupations (SHEO) Among DOE Sites Participating in Epidemiologic Surveillance, 1997

NERVOUS SYSTEM n =73

ICD Code	Frequency	Description
354.1.1	68	carpal tunnel syndrome
354.2	1	mononeuritis of upper limb (lesion of ulnar nerve)
366.9	1	unspecified cataract
369.60	1	profound impairment one eye, unspecified

372.40	1	pterygium, unspecified
386.50	1	labyrinthine dysfunction, unspecified

CANCER n = 13

ICD Code	Frequency	Description
162.9	7	malignant neoplasm of bronchus and lung, unspecified
188.9	3	malignant neoplasm of bladder, part unspecified
189.0	3	malignant neoplasm of kidney, except pelvis

RESPIRATORY n = 2

ICD Code	Frequency	Description
465.9	1	acute respiratory infection, NOS
473.9	1	sinusitis, NOS
486	1	pneumonia, organism unspecified
490	2	bronchitis, NOS
493.0	1	extrinsic asthma
500	1	coal workers' pneumoconiosis

Reference: Rutstein DD, Mullan RJ, et al. 1984. Sentinel health events (occupational): A basis for physician recognition and public health surveillance. *Arch. Envir. Health* 39: 159-168.

2) **CAIRS**

The Computerized Accident/Incident Reporting System (CAIRS) is a database used to collect and analyze DOE and DOE contractor reports of injuries, illnesses, and other accidents that occur during DOE operations. CAIRS data consist of DOE and DOE contractor reports of injuries and illnesses, property damage, and vehicle accident events. The Occupational Safety and Health Administration's guidelines for reportable cases are used to determine the eligibility of injury/illness cases for reporting to CAIRS.

Most injuries have an immediate, specific cause, facilitating the determination of whether they are occupational. Many other health effects may be less clearly associated with occupational exposures or may develop over a substantial period of time. In general, the CAIRS system best captures information on acute illnesses associated with an event that results in lost time. The system tends to underreport illnesses that are not clearly associated with work and/or chronic progressive illnesses that may not result in lost time.

An effort to summarize these less immediate health effects is presented in the table presented below. They are based on CAIRS data reflecting these selection criteria:

1. All DOE sites included
2. Conditions other than injuries

3. Contractor workers (not Federal employees)
4. Events occurred during calendar year 1998

The CAIRS data base does not include International Classification of Disease (ICD) codes, using instead a health effect classification system containing a number of broad categories of health effects. Where the CAIRS classification scheme uses these broad categories, no more detailed coding of health effects was available for analysis.

Table 2

Non-Injury Occupational Health Effects among Contractor Workers at all DOE Sites, 1998

Non-Injury Occupational Health Effects among Contractor Workers at All DOE Sites, 1998					
Health Effect	**Number of Events**	**Total Lost Workdays**	**Average* Lost Workdays per Event**	**Total Restricted Workdays**	**Average* Restricted Workdays per Event**
Effects of Environmental Conditions					
Heat stroke, other effects of high temperatures	27	7	<1	7	<1
Other Poisonings and Toxic Effects					
Chemical reactions	4	0	0	398	100
Other poisoning or toxic effects**	6	6	1	4	1
Nervous System and Sensory Organ Diseases					
Carpal tunnel syndrome	77	776	10	912	12
Conjunctivitis	2	0	0	0	0
Central nervous system disorders	1	3	3	21	21
Hearing impairment	2	0	0	0	0
Hearing loss	7	0	0	0	0
Other nervous system and sensory organ diseases**	75	99	1	473	6
Diseases of the Heart or Circulatory System					
Other circulatory system disorders**	1	0	0	0	0
Respiratory System Diseases					
Asbestosis	1	0	0	0	0
Berylliosis	2	0	0	0	0
Upper respiratory conditions	8	2	<1	1	<1
Other respiratory diseases**	25	42	2	49	2
Digestive System Diseases and Disorders					
Other digestive system diseases**	1	0	0	2	2

Musculoskeletal System and Connective Tissue Diseases and Disorders					
Bursitis	1	0	0	0	0
Tendonitis	95	77	1	574	6
Tenosynovitis	7	18	3	42	6
Other musculoskeletal disorders**	134	287	2	1099	8
Disorders of the Skin and Subcutaneous Tissue					
Allergic dermatitis	4	0	0	0	0
Contact dermatitis	18	0	0	84	5
Dermatitis	12	0	0	18	2
Other skin conditions**	36	3	<1	52	1
Other Systemic Diseases and Disorders					
Other systemic diseases and disorders**	22	29	1	108	5
Infectious and Parasitic Diseases					
Infections	3	14	5	0	0
Symptoms, Signs, and Ill-defined Conditions					
Inflammation	10	22	2	152	15
Irritation	4	0	0	0	0
Other symptoms, signs, and ill-defined conditions**	64	154	2	324	5
Other Diseases, Conditions, and Disorders					
Mental disorders	5	313	63	116	23
Other diseases, conditions, and disorders**	2	40	20	35	18
Multiple Diseases, Conditions, and Disorders					
Multiple diseases, conditions, and disorders	3	0	0	4	1
Total	659	1892	3	4475	7

*Rounded to the nearest full day
**No finer category breakdown available within CAIRS

APPENDIX 10

SUMMARY OF INITIAL RESULTS FROM THE FORMER WORKER PROGRAM

Background

The Former Workers Program was created at the Department of Energy in response to Public Law 102-484, enacted in 1993. Section 3162 of this law directed DOE to evaluate the long-term health conditions of current and former employees who may be at significant risk of adverse health effects as a result of their employment at DOE sites. To meet these requirements, DOE established the Former Workers Program in October 1996.

The Former Workers Program is divided into two stages: Phase I and Phase II. In 1996, DOE began to support Phase I activities consisting of needs assessments to identify groups of former workers who may benefit from a medical surveillance program. In addition, Phase I was designed to determine if enough information on current and former workers is available to proceed with Phase II. During Phase II, current and former workers are contacted and medical surveillance programs are implemented based on the exposures most likely to produce adverse health effects. The projects are being conducted by cooperative agreements with consortia of universities, unions, and other organizations.

As mandated by the law, the DOE Former Workers Program screens workers who are at high risk. As of November, 1999, DOE supported 10 former workers projects at 9 DOE sites.

The table below presents a summary of chest X-ray screening conducted for 709 former workers at three DOE sites. These X-rays are read by individuals ("B-readers") with specialty training in recognition of pneumoconioses. The International Labor Organization (ILO) in Geneva, Switzerland, publishes criteria to allow for the standardization of reading chest X-rays. The first number indicates the major category of profusion of abnormal opacities on the film which is based on the concentration or number of small opacities per unit area observed within the lung fields. The second number indicates whether the number of opacities is judged to be less than, equal to, or more than the profusion level expected for the major category.

Categories 0/-, 0/0, and 0/1 are generally regarded as exhibiting no evidence of pneumoconiosis. Chest X-rays in profusion categories 1/0, 1/1, 1/2 or higher are generally regarded as positive for pneumoconiosis.

Of the 882 individuals screened to date, 148 (17%) have category 1/0 or greater perfusion on their chest X-ray.

In addition, 243 workers have been screened at the three DOE gaseous diffusion plants. Of this number, 28 workers (11.5%) were found to have asbestos-related fibrosis. The results of the ILO Perfusion scores were not available at the time of this report.

Data regarding other disease endpoints such as hearing loss were presented to the panel and are being accumulated as part of this program but were felt to be too preliminary for this report.

Summary for Respiratory Findings for DOE Former Workers

ILO Perfusion	Hanford Construction	Hanford Production	Nevada Test Site – Tunnelers	Oak Ridge Construction	TOTAL
0					
0/0	5 [8%]	175 [86%]	203 [37%]	53 [8%]	436 [49%]
0/1	29 [47%]	14 [7%]	255 [46%]	0	298 [34%]
1/0	12 [21%]	8 [4%]	59 [11%]	4 [6%]	83 [9%}
1/1	8 [13%]	4 [2%]	19 [3%]	3 [5%]	34 [4%]
1 /2	3 [5%]	2 [1%]	5 [1%]	2 [3%]	12 [1%]
2/1	3 [5%]		5 [1%]	0	8 [1%]
2/2	0		5 [1%]	0	5
2/3	1 [2%]		2 [.4%]	0	3
3/2+	0		3 [.5%]	0	3
Total Number	61	203	556	62	882

APPENDIX 11

SUMMARY OF PUBLIC INPUT AND NEWSPAPER REPORTS

Input for Public Meetings

Beginning in August 1999, the Department of Energy initiated a number of outreach efforts to learn more about work-related health concerns from its current and former contractor workforce. DOE's Assistant Secretary for Environment, Safety and Health, Dr. David Michaels, held a series of public meetings in the communities surrounding current and former DOE facilities. The purpose of these meetings was to seek direct input from workers regarding their health concerns and experiences with filing for workers' compensation for these health problems. At all sites, in addition to the public meetings, several separate meetings were held with small groups of workers and their families.

The following is a listing of the dates, location and attendance of these public meetings:

Date	Location	# Attended	# Testified	Secretary/Members of Congress
8/1	Paducah	200	20	
9/16-17	Paducah	250	20	Secretary Richardson
10/29-30	Portsmouth	250	50	Senator Voinovich, Senator DeWine Congressman Strickland
11/15	Los Alamos*	50		
12/8-9	Oak Ridge	575	65	
12/15-16	Rocky Flats	275	50	Congressman Udall
1/6	Burlington	125		Secretary Richardson Senator Harkin

* - closed invitation only community meeting sponsored by unions and community groups.

Additional public meetings are planned for Hanford (February 2-4), Nevada (February) and Los Alamos (March).meetings:

Toll-Free Hotline and Questionnaires

In August 1999 the DOE established a toll-free "hotline" for workers to call in to ask questions and to relay any health concerns. As of January 19, 2000, the hotline has received 610 calls.

To assist in writing the Task 2 report, a questionnaire was distributed at the public meetings mentioned above and by labor unions at these sites asking DOE employees about health concerns and their experience with workers' compensation systems. Workers were given the option of completing the questionnaire over the telephone using the toll-free hotline. To date, 435 questionnaires have been completed: 368 over the phone; 67 mailed in. Of these 435 completed questionnaires, 318 records have been analyzed. Roughly 58% (183 of 318) have reported some type of illness or disease as follows:

Type of Illness	# (%)
Cancer	84 (46%)
Beryllium	10 (5%)
Lung Disease	15 (8%)
Asbestosis	6 (3%)
Other	68 (37%)
TOTAL	183

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APPENDIX 12
LIST OF PANEL MEMBERS

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